

# Immunoglobulins - Novel solutions for swine health



## *Conference Report*

Unlike humans and most mammals, piglets do not receive any maternal immunoglobulins (antibodies) via the placenta. Therefore, it is vital for piglets to receive maternal antibodies via the colostrum within 24 hours of birth. Otherwise, they are more vulnerable to illnesses in their early stages of life. In situations where piglets do not receive enough colostrum, such as due to large litter sizes or weak sows following a prolonged farrowing — supplemental colostrum or IgY products can provide essential immune protection.

In the following, Dr. Shofiqur Rahman describes the innovative role of IgY – yolk immunoglobulins in enhancing swine health.

## **IgY – modes of action**

IgY is an antibody found in egg yolk. It is an entirely natural product; each egg contains approximately 100 mg of IgY. These egg-derived antibodies primarily function in the gut through several mechanisms:

- Adherence inhibition – IgY antibodies bind to specific structures on the surface of pathogens (such as fimbriae, flagella, and lipopolysaccharides), preventing them from adhering to the intestinal mucosa and blocking the initial stages of infection. This is particularly significant for enterotoxigenic *E. coli* (ETEC), which causes piglet diarrhea by attaching to intestinal cells.
- Neutralization – IgY can neutralize toxins produced by pathogens, preventing them from exerting harmful effects on host cells.

- Agglutination – IgY promotes the clumping of pathogens by binding them together, effectively immobilizing them, and facilitating their removal from the animal's gut.
- Cell damage – IgY can damage the integrity of bacterial cell walls leading to cell lysis and reduced bacterial viability.

Furthermore, because these pathogens are bound in complexes with IgY and eliminated through feces in an inactivated form, IgY helps prevent environmental re-infection through manure.

## IgY and IgG – functional differences

Both IgY and Immunoglobulin G (IgG) (IgG, the most abundant immunoglobulin in mammals) are antibodies. They, however, exhibit significant differences due to their distinct structural characteristics. “IgY, for instance, does not activate the complement system, a key function of IgG that enhances immune responses against infections. Additionally, IgY promotes more rapid phagocytosis and reduces inflammation compared to IgG. These effects contribute to energy conservation, thereby facilitating improved animal growth performance,” he explained.

IgY is more hydrophobic than IgG, which increases its stability and resistance to proteolytic degradation. This property is beneficial for maintaining its functionality in the gastrointestinal tract.

## Production and quality control

IgY develops in hens in response to the pathogens they encounter, regardless of their relevance to the hens themselves. For instance, hens immunized with an infectious pathogen affecting pigs can produce IgY, effectively preventing the disease caused by that pathogen.



There are different methods of IgY production. One possibility is to hyperimmunize the hens simultaneously with multiple antigens. This method seems convenient, but it does not produce products with standardized levels of immunoglobulins for each antigen.

Another approach involves immunizing different groups of hens, each with a single antigen (e.g., transmissible gastroenteritis virus, rotavirus, *E. coli*) that commonly challenges piglets during the first weeks of life. The immunoglobulin content is then quantified, and the resulting egg powders are spray-dried, pasteurized, and mixed. This process yields an IgY product with standardized amounts of specific immunoglobulins that exhibit high affinity for the target pathogens.

# One health application in swine

“The benefits of IgY have been demonstrated through extensive trials and commercial experiences, highlighting its potential for various applications not only in swine but also in other animals and humans,” said Dr. Rahman.

Due to concerns about antibiotic resistance, regulatory and consumer scrutiny increased over the use of in-feed antibiotics. IgY can serve as an effective and natural alternative for improving overall gut health, reducing the incidence and severity of diarrhea, reducing morbidity during the critical pre- and post-weaning periods, and, thereby, increasing performance.

Unlike antibiotics, which can indiscriminately kill both harmful and beneficial bacteria, IgY selectively targets specific pathogens. This selective action helps maintain a balanced gut microbiome, which is crucial for overall health and digestion in piglets. Disruption of the gut microbiota by antibiotics can lead to issues such as antibiotic-associated diarrhea and increased susceptibility to opportunistic infections due to the loss of beneficial microbes.

In contrast to antibiotics, IgY targets multiple antigenic sites on pathogens, requiring various genes for their protection, thereby avoiding resistance issues among pathogenic microorganisms. Additionally, IgY is effective not only against bacteria but also demonstrates significant efficacy against viruses and coccidia.

## Conclusion

Dr. Rahman concluded that “the use of IgY as a passive immunization strategy, incorporated into a holistic approach to reducing piglet diarrhea, offers a safe and natural alternative to traditional antibiotics, particularly in the light of rising antibiotic resistance and the need for effective treatments also for viral diseases.”

EW Nutrition’s Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Shofiqur Rahman, Senior Researcher at the Immunology Research Institute Gifu (IRIG) in Japan was one of the highly experienced speakers of EW Nutrition. Originally a microbiologist, Dr. Rahman focuses on researching and developing IgY products for Human, Animal, Pet, Fish, Plant, and Environmental health.

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# Start right with your piglet nutrition



#### *Conference Report*

“A good start is half the battle” can be said if we talk about piglet rearing. For this promising start, piglets must eat solid feed as soon as possible to be prepared for weaning. Dr. Jan Fledderus, Product Manager and Consultant at the S&C team at Schothorst Feed Research, shows some nutritional measures that can be taken to keep piglets healthy and facilitate the critical phase of weaning.

## **Higher number of low-birth-weight pigs in larger litters**

Litter size affects piglet quality. Larger litter sizes from hyperprolific sows often result in higher within-litter variation in birth weights. This variability can lead to a higher proportion of low-birth-weight piglets, which are more susceptible to health issues and have lower survival rates. Additionally, low birthweight pigs have an increased risk of mortality, and an improvement in birth weight from 1kg to 1.8 kg can result in 10 kg more body weight at slaughter.



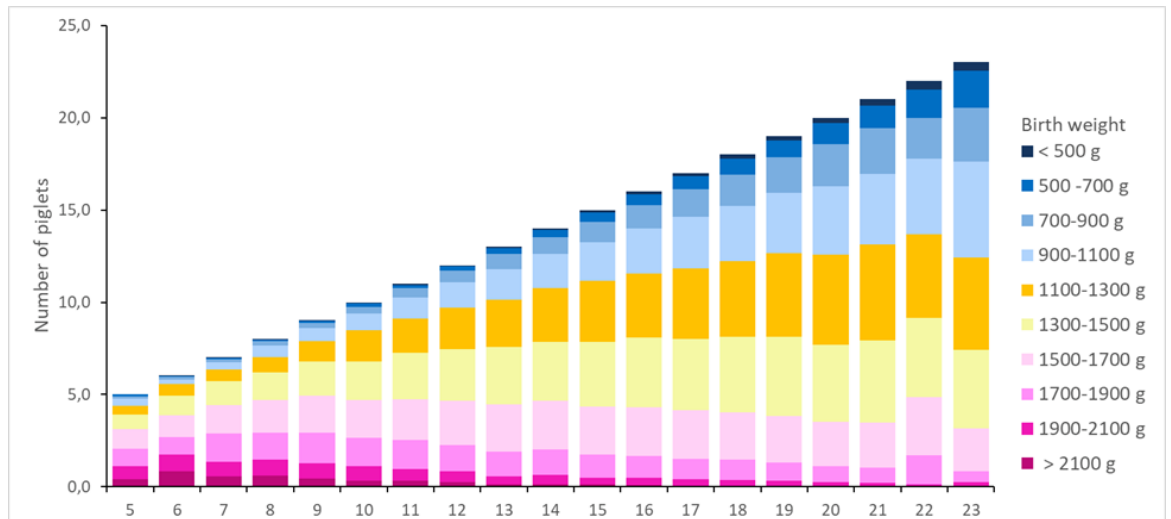


Figure 1: Effect of litter size on birth weight distribution (Schothorst Feed Research Data were collected from 2011 to 2020, based on 114,984 piglets born alive from 7,952 litters).

Implementing management practices for low-birth-weight pigs, such as split suckling, can significantly enhance nutrient intake, support immune function, and ultimately contribute to better survival rates and overall health for these vulnerable piglets.

## Weaning age determines intake of creep feed

Pigs that consume creep feed before weaning restart faster to eat, have a higher feed intake, and less diarrhea after weaning. For instance, in a field trial, pigs that consumed feed 10 days before weaning had a 62% incidence of diarrhea, whereas in pigs that consumed feed only 3 days pre-weaning, diarrhea incidence increased to 86%.

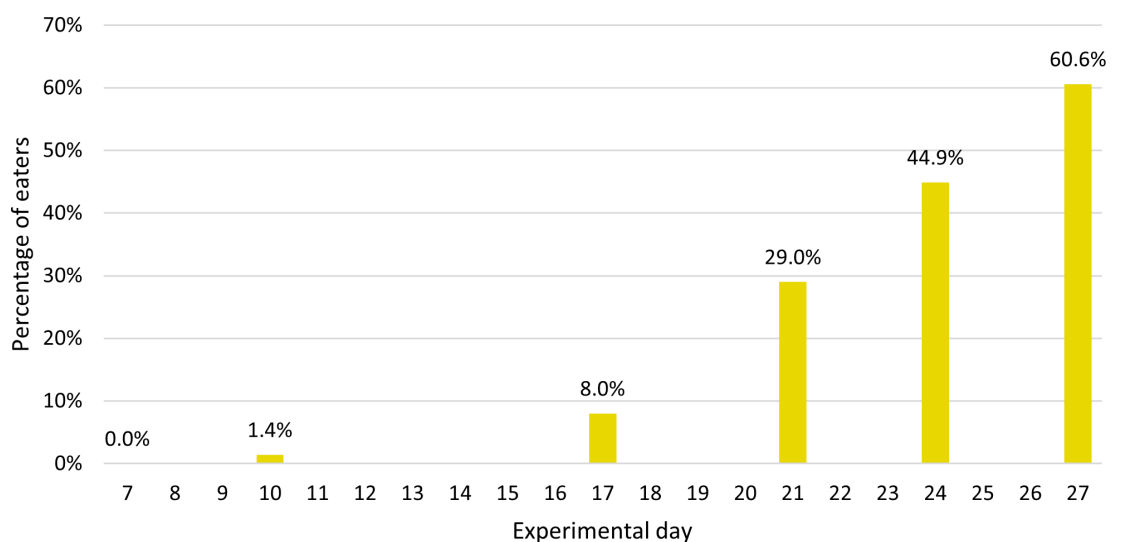


Figure 2: Influence of age on the percentage of pigs consuming creep feed

“As age is the most critical factor for a high percentage of pigs eating before weaning, there is a trend in the EU to increase the weaning age, where some farmers go to 35 days,” remarked Dr. Fledderus.

Furthermore, weaning age is positively correlated with weaning weight. Every day older at weaning improves post-weaning performance and reduces health problems.

# Feed management

Creep feed for 7-10 days pre-weaning is essential, not to increase total feed intake, but to train the piglet to eat solid feed to avoid the 'post-weaning dip.' After about 15 days of age, piglets can consume more than is provided by milk alone. Dr. Fledderus strongly recommended creep feeding for at least one week before weaning. "Consuming feed before weaning will result in fewer problems with post-weaning diarrhea," he said.

In addition to creep feeding, a transition diet, from 7 days pre- and 7 days post-weaning, is advised. The composition or form of the transition diet should not be changed.

The key objective of post-weaning diets is to achieve a pH of 2-3.5 in the distal stomach. Pepsin, the primary enzyme responsible for protein digestion, is activated at a pH of around 2.0. Its activity declines significantly at a pH above 3.5, which can lead to poor protein digestion and nutrient absorption.

## Fiber as a functional ingredient

Fiber was previously considered a nutritional burden or diluent, but now it is regarded as a functional ingredient. Including dietary fiber, mainly inert fiber such as rice or wheat brans, can increase the retention time of the digesta in the stomach. This extended retention allows for more prolonged contact between digestive enzymes and nutrients, facilitating improved digestion and absorption of proteins and other nutrients. Not only is pH reduced, but because more proteins are hydrolyzed to peptides, there is less undigested protein as a substrate for the growth of pathogenic bacteria and the production of toxic metabolites in the hindgut.

"Size of fiber particles also matters," said Dr. Fledderus. Coarse wheat bran particles (1,088 µm) have been shown to be more effective than finer particles (445 µm) in reducing E. coli levels in the gut. The larger particle size helps prevent E. coli from binding to the intestinal epithelium, allowing these bacteria to be excreted rather than colonizing the gut.

The understanding of dietary fiber's role in pig nutrition has evolved, with recent findings indicating that fiber can actually increase feed intake in piglets, contrary to earlier beliefs that it might decrease intake. High-fiber diets often increase feed intake as pigs compensate for lower energy density. This can help maintain growth rates when formulated correctly.

EW Nutrition's Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Jan Fledderus, Product Manager and Consultant at the S&C team at Schothorst Feed Research, one of the founders of the Advanced Feed Package and with a strong focus on continuously improving the price/quality ratio of the diets for a competitive pig sector, was a reputable guest speaker in these events.

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## Rearing pigs without antibiotics



### *Conference Report*

Holistic management is essential for successfully rearing pigs, particularly in systems that aim to minimize antibiotics. The method emphasizes the interconnectedness of various factors contributing to sustainable pig health and productivity. Some of the key components of this holistic management were discussed by Dr. Seksom.

## **Sow lifetime productivity**

Suggested targets for sow lifetime productivity are

- >70 marketed fattening pigs
- At least 6 parities with at least 10.5 pigs marketed per parity
- 25 fattening pigs/sow/year (2.4 parities/year x 10.5 fattening pigs)

To achieve these targets, we need 29.2 born alive piglets/sow/year (or 12.2 born alive piglets/parity), and it is essential to control losses during each production period: <10% pre-weaning, <3% during nursery, and <2% in fattening.

Since the occurrence of African swine fever (ASF), with improved genetics, we can now produce pigs with 120 kg+ bodyweight at slaughter without carcass problems and reach about 3 tons of bodyweight/sow/year, compared to around 2 tons before.

## **Modern pig genetics and subsequent**

# problems

Despite the advancements in modern pig genetics leading to improved production and bigger litters, several ensuing problems have emerged:

- Less average body weight of piglets at birth
- Large number of piglets born with less than 1.0 kg (target <5%)
- High pre-weaning mortality
- High post-weaning mortality and morbidity

Dr. Seksom highlighted that birthweights decrease with increasing sow prolificacy. He stated that “piglets should be divided into groups with similar body weights at weaning” and that “a key objective for successful weaning is a piglet that weighs a minimum of 6-6.5 kg at three weeks of age, and that less than 25% of the piglets have a weight of  $\leq 5.9$  kg.”

## Sow body condition

Sows should be fed to feed to body condition score (BCS), not a fixed amount of feed. Ideally, the sows have a BCS of 2.75 (the sow's backbone is visible, and the tips of the short ribs can be felt but are smooth) or 3.0 (well-rounded appearance, hips, and spine can only be felt with firm pressure) at 12 weeks of pregnancy, so we can feed more in the last month to achieve a BCS of 3-3.25 at farrowing. This is essential to ensure that sows have sufficient energy reserves for lactation and overall health.

Target body condition score – 2.75 at three months of gestation



Feed intake must be increased gradually during the last month of gestation as most fetal growth and mammary gland development occur during this period. This may involve raising energy-dense feeds or adjusting protein levels as needed.

Dr. Seksom stressed that “nutrition is not just the feed; it's about feeding as well. To feed sows to BCS, assessments of BCS should be done regularly throughout gestation, ideally every 2-4 weeks. This allows for timely adjustments in feeding based on individual sow's needs. Ensure that staff are trained one-on-one to accurately assess the body condition of sows. This includes recognizing the visual and tactile indicators of different scores and understanding how BCS impacts reproductive performance, longevity, and overall farm profitability.”

After farrowing, the sows must be monitored closely for any signs of excessive weight loss and feeding strategies adjusted accordingly to support recovery and lactation needs.



# Piglet diarrhea

Many factors cause diarrhea and must be thoroughly investigated. For bacteria-caused diarrhea, Dr. Seksom advised a good hygiene program, whereas for viral causes, a vaccination program is essential. However, he emphasized that “for a vaccination program, you can’t just copy from another farm; it needs to be created specifically using the titers for diseases on your farm.”

Swine influenza is an often-overlooked cause of diarrhea in piglets. While it is primarily recognized for causing respiratory issues, the virus can also lead to scours in the first two weeks of piglets’ life. So, sows should be checked for symptoms of swine influenza (such as nasal discharge, sneezing and coughing, and inappetence) before farrowing. If necessary, they must be treated with paracetamol to reduce fever and symptoms.

## Main disease causes of pre-weaning diarrhea

|                | Nursery period |          |           |            | Mortality level |
|----------------|----------------|----------|-----------|------------|-----------------|
|                | Days 1-3       | Days 3-7 | Days 7-14 | Days 14-21 |                 |
| Agalactia      | ✓              | ✓        | ✓         | ✓          | Moderate        |
| Clostridia     | ✓              | ✓        | ✓         |            | High            |
| Coccidiosis    |                | ✓        | ✓         | ✓          | Low             |
| <i>E. coli</i> | ✓              | ✓        | ✓         |            | Moderate        |
| PED            | ✓              | ✓        | ✓         |            | Variable        |
| PRRS           | ✓              | ✓        | ✓         | ✓          | Variable        |
| Rotavirus      |                |          | ✓         | ✓          | Low             |
| TGE            | ✓              | ✓        | ✓         | ✓          | High            |
| Influenza      |                | ✓        | ✓         |            | Low             |

# Ensuring colostrum intake

The intake of an adequate quantity of colostrum is crucial for piglets to be protected during the first days of life. Best practices to ensure that piglets get ≥250 mL of colostrum include:

- **Teat access** - if a sow has a large litter or is unable to nurse all her piglets effectively, consider split suckling by separating larger, more vigorous piglets from the litter for a couple of hours after birth. This allows smaller or weaker piglets better access to the udder without competition. Syringe-feeding colostrum to smaller piglets is also effective.
- **Early access** - six hours after farrowing, the quality of colostrum begins to decline significantly. Additionally, the piglet can only absorb intact large IgG molecules, the major source of passive immunity, during the first 24 h after birth, prior to gut closure. In any case, by this time, the sow will start producing milk and not colostrum.
- **Sow behavior** - if a sow experiences pain or discomfort from injuries caused by her piglets’ teeth, she may become less willing to allow them to nurse, leading to delays in colostrum intake. Genetic background influences maternal behavior significantly. For example, some breeds exhibit stronger maternal instincts and better nursing behaviors than others. Selecting sows with proven good maternal traits can lead to improved outcomes in piglet survival and growth.
- **Drafts** - newborn piglets are born with low fat reserves and are highly susceptible to hypothermia. Drafts significantly impact the effective temperature experienced by piglets.
- **Staff training** - Staff must be trained to recognize signs of distress in both sows and piglets; training in techniques enables them to assist with nursing and feeding, which is crucial for timely interventions.



## Weaning is a process, not just a one-time event

Research has shown that heavier piglets at weaning have better lifetime performance than lighter ones. Weaning weight is a more accurate indication of post-weaning growth than either birth weight or age. It is, therefore, important to establish the weaner immediately post-weaning to maintain growth rates, reduce pen variation, and lessen the amount of 'tail-enders' at the point of sale.

Dr. Seksom emphasized that "viewing weaning merely as a single event, rather than a process, overlooks the complexities involved in ensuring a smooth transition for the animals. He advocated for a comprehensive approach to weaning that includes the shown well-planned steps to support piglets during this critical phase. If the weaning process is managed effectively, you can significantly reduce the need for antibiotics."

### Conclusion

"By integrating these holistic management strategies, pig producers can effectively raise pigs without antibiotics while promoting animal health, improving productivity, and addressing consumer concerns about antibiotic use in livestock production," summarized Dr. Seksom.

EW Nutrition's Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Seksom Attamangkune, a leading expert in the nutrition and management of pigs in tropical conditions and former Head of the Animal Science Department and Dean of the Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, was a reputable guest speaker at this event.

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# Building and boosting the immunity shield of pigs



*Conference report*

A well-functioning immune system is vital for the survival and performance of animals. It helps piglets cope with challenging periods, such as their first days of life or weaning. Measures can be taken around farrowing to support the piglets during their first days by enhancing the quality and quantity of colostrum and helping them develop their own immune system as fast as possible.

## Adequate feeding of the sow before and around farrowing

Feeding of both the sow and the piglet has an important influence on farrowing, the health of the sow, colostrum and milk production, piglets' development of immunity, and their later performance. A well-functioning immune system is crucial for the piglets to withstand upcoming challenges such as weaning.

## Colostrum quality can be influenced by feeding

Newborn piglets have no functioning immunity system. They rely entirely on immunoglobulin G (IgG) absorption from colostrum within the first few hours after birth to establish their immunity shield. Dr. Megan Edwards, Animal Nutrition Consultant from Integral Nutrition (S) Pte Ltd, highlighted the payback of adequate colostrum quality and intake: Adequate colostrum intake can positively affect whole-of-life

immunity and, ultimately, growth performance. The contained IgG is essential for providing passive immunity to piglets, protecting them from infections during their early days of life when their immune systems are still developing. There is a positive correlation between the amount of IgG they absorb from colostrum and their performance. This benefit of colostrum intake is independent of birth weight.

We have a 3-week window to influence colostrogenesis. However, the fat content of colostrum is determined in the last 48 hours before farrowing. According to Dr. Edwards, influencing colostrum quality is generally easier than affecting quantity. She identified several compounds that can serve as immunomodulators, such as MCFAs, yeast extracts, and butyrate. However, by moving IgG to colostrum and milk in late gestation and lactation, the sow compromises her immunity status by depleting her own reserves for about two weeks.

## **Feeding at farrowing**

Sow body condition has been shown to have more impact on colostrum yield than feeding level. The highest colostrum yield was achieved when sows entered the farrowing unit with a moderate body condition (3-3.25 – the ribs, spine, and hip bones can only be felt with firm pressure but are not visibly prominent). Overfeeding should be avoided to prevent sows from becoming excessively fat pre-farrowing.

Sows experience increased energy demands during farrowing due to the physical demands of parturition and the physiological changes occurring in their bodies. Dr. Edwards does not encourage withholding feed on the day of farrowing and suggests offering up to 3kg if the sow has the appetite. Feeding just below the energy requirement helps the sow to mobilize her own body fat.

Many producers mistakenly withhold feed on the day of the farrow to reduce the incidence of constipation. Feeding, however, stimulates gut motility. Withholding feed can slow down gut transit time and actually increase the likelihood of constipation.

## **Piglet feeding for developing intestinal tract and immune system**

In piglet feeding, two strategies are decisive: the early intake of immunoglobulins via colostrum to protect the piglets against pathogens during their first days of life and the offering of creep feed to stimulate their intestinal development.

## **High-quality colostrum as much and as soon as possible**

When the piglets are born, it is of the highest importance that they ingest colostrum as much and as soon as possible. The piglet can only absorb intact large IgG molecules, the primary source of passive immunity, before gut closure, which begins about 6–12 hours after birth and progresses rapidly to completion in about 24 hours. In any case, the sow will start producing milk by this time and no more colostrum. The concentration of colostrum IgG decreases by 50% within 6 hours after the birth of the first piglet. The target is for piglets to consume 250 g of colostrum within the first 24 hours, ideally within the first 6 hours. However, about 30% of sows produce insufficient colostrum.



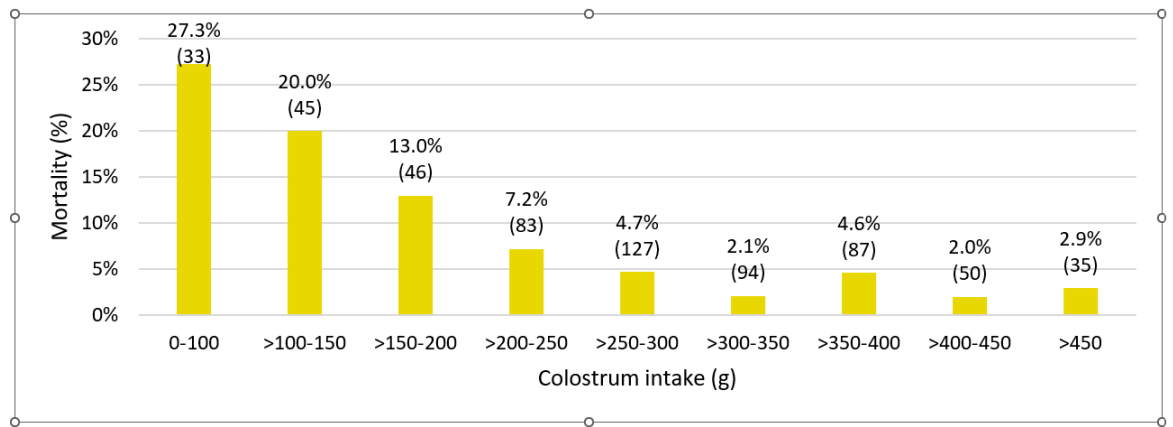


Figure 1: Mortality of piglets until 42 days of age according to intervals of birthweight and colostrum intake

(Hasan et al. 2019; the numbers of piglets are shown in parenthesis)

## Split suckling jump-starts weak piglets

Split suckling is an effective management strategy to improve piglets' access to colostrum and milk, particularly in increasingly common situations where sows give birth to large litters. This involves temporarily separating the more vigorous piglets from the sow to allow smaller or weaker piglets better access to the teats. This method helps ensure that all piglets receive adequate nutrition during the critical early hours after birth.

## Large litters provoke energy deficiency in piglets

Piglets are born with limited energy reserves (glycogen and brown fat tissue). Ingestion of colostrum is associated with a considerable increase in the metabolic rate, contributing to maintaining body temperature. About 70% of the piglets' energy requirement in the first 72 hours is provided by colostrum. "Most piglets that die within this period do so primarily due to energy deficiencies rather than immune-related issues. The trend towards larger litter sizes has exacerbated the issue of energy deficiency," stated Dr. Edwards.

## Creep feeding

The primary role of creep feed is to accelerate the development of the piglets, their digestive and immune systems, and their gut microbiome, not for weight gain. Creep feeding helps evolve digestive enzymes and acid secretion necessary for breaking down complex carbohydrates and proteins. This early feeding supports piglets in adapting to solid diets, mitigating stress during weaning.

Creep feeding also helps piglets develop an oral tolerance to avoid transient hypersensitivity due to various dietary ingredients. This process is essential for preventing allergic reactions and hypersensitivity, which can occur when the immune system mistakenly identifies harmless substances as threats. It takes about two weeks for the piglet to recognize an ingredient as a nutrient, not a pathogen. To facilitate this process, she recommends that creep diets contain a broad range of ingredients at low doses. This approach gradually exposes piglets to various nutrients, allowing their immune systems to adapt without overwhelming them with high concentrations of any single ingredient.

## Mycotoxins must be managed - even in piglets

The significance of mycotoxins in piglets is often underestimated due to their relatively small feed intake. However, there is substantial evidence that mycotoxins can be transferred from sows to piglets through colostrum and milk, which can have profound health implications.

Dr. Edwards is convinced that managing mycotoxins is managing immunity. Mycotoxins are transferrable

via the placenta, colostrum, and milk. There is a positive correlation between the mycotoxin levels in feed and colostrum. For example, adverse effects seen in piglets consuming colostrum with low doses of deoxynivalenol (DON) include:

- Decreased villus height
- Reduced mucosal integrity
- Increased inflammation
- Alternated immune response

The bottom line is that mycotoxins are a real and everyday risk to the immune quality of your piglets.

## **Nutrition influences piglets' immune development**

Dr. Edwards summarized that adequate nutrition is fundamental for developing a strong immune system in pigs, which is the basis for high performance. By focusing on the appropriate nutrition of the sow, ensuring an adequate intake of high-quality colostrum intake in piglets, and implementing creep feeding strategies, producers can significantly enhance the lifetime health and productivity of their piglets from an early age.

EW Nutrition's Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Megan Edwards, an Australian animal nutrition consultant with global research and praxis experience and a keen interest in immuno-nutrition and functional nutrients, was an esteemed guest speaker at this event.

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## **Optimising Weaner Performance**



### *Conference report*

To optimize weaner performance, it is helpful to understand the stressful situation the piglets are facing. In contrast to weaning in nature, which occurs gradually until completion at approximately 4-5 months, weaning in intensive pig operations is an acute process, typically occurring at 3-4 weeks of age. This critical phase subjects piglets to multiple stressors, which can have cumulative effects on their health and development.

Furthermore, the weaning process usually coincides with a decline in the levels of maternally derived antibodies. As these antibody levels decrease, piglets become increasingly susceptible to infections, particularly during the stressful transition to solid food and movement from the sow to the new nursery environment. Managing the weaning process carefully is crucial to minimize stress and support immune function.

## **Weaning factors that influence a successful weaning**

Several aspects must be considered to provide the weaning piglets with the best conditions, and diverse measures must be taken. These measures range from the social environment to nutrition, hygiene, and the people dealing with the pigs.

### **Social dynamics**

When forming nursery groups, aim to keep pigs in these groups as long as possible. Moving all pigs to their new environment at the same time can promote a more rapid establishment of social stability. If possible, once weaning groups are selected and placed in the nursery, keep these groups together to harvest. Any change in the pig group will again result in the need for a new hierarchy to be established, along with fighting and disrupting the group. "Allow newly selected nursery groups to establish their hierarchy by avoiding interventions during the first 48 hours, except to treat sick or injured pigs", recommends Dr. Parke. "A well-enriched environment, such as chewable ropes and toys, can help reduce stress levels and

may reduce the frequency of abnormal behaviors such as tail biting and aggression.”

## Environmental management

The piglets should be kept at an optimal temperature between 27-30°C – depending on floor type, weight, and age of piglets. Adding a heat lamp/floor mat warm area for just-weaned piglets will further assist thermoregulation and minimize stress through the weaning transition.

Proper ventilation is crucial for maintaining air quality and preventing the buildup of harmful gases like ammonia. Good airflow helps regulate temperature and humidity, reducing stress on the pigs. However, care must be taken to avoid drafts that can chill young pigs. For example, a draft of 0.5 m/second can ‘feel’ like an 8°C drop for the piglet.

### Targets for gas, dust, and bacteria levels

| Risk factor   | Gas                 |                   |                               | Total dust           | Respirable dust       | Bacteria                   |
|---------------|---------------------|-------------------|-------------------------------|----------------------|-----------------------|----------------------------|
|               | Ammonia             | Hydrogen sulphide | Carbon dioxide                |                      |                       |                            |
| Target levels | <10ppm (20ppm max.) | <5ppm             | <3,000ppm (aim for <1,500ppm) | 2.4mg/m <sup>3</sup> | 0.23mg/m <sup>3</sup> | 100,000 CFU/m <sup>3</sup> |

Flooring and pen materials should be robust, in good condition, and easily cleaned to reduce the risk of skin abrasions and subsequent infections.

Provide sufficient space (recommended 0.19 m<sup>2</sup>/8 kg pig on slat/solid floor) in pens to minimize competition for feed and water and to reduce social stress among piglets.

Weaner pigs benefit from using the same type of feeder in the nursery as in the farrowing room. This consistency can help to reduce stress and anxiety during the transition to the nursery and increase the feed intake during the first few days post-weaning.

## Nutritional support

Weaning stress and poor feed intake post-weaning commonly result in dysbiosis and a decrease in villus height in the small intestine of piglets. Associated digestive impairment and altered gut morphology can lead to decreased nutrient absorption, as well as enteric and systemic health issues. A palatable transition diet, from 7 days pre- to 7 days post-weaning, is recommended to keep piglets eating. The composition or form of the transition diet should remain the same during this period. Consider using functional feed additives, such as phytomolecules or egg immunoglobulins, to support microbial modulation and gut integrity.

Ensure piglets have access to fresh, cool, and clean water (minimum water flow of 0.5-0.7L/minute), with enough drinking space (maximum of ten piglets per drinker). Consider providing additional water supply points (e.g., bowls) in the first week.

## Hygiene and biosecurity

All-in, all-out management avoids the mixing of different age groups. It is particularly beneficial for weaner pigs, as it helps minimize disease transmission. After removing each batch of weaners, the nursery must be thoroughly cleaned, disinfected, and dried. This includes not just the floors but also feeders, waterers, and any equipment used in the room.

There should be strict rules for everything that comes through the external perimeter fence. Internal biosecurity is also essential, e.g., changing into clean, disinfected boots and thoroughly washing hands when moving between rooms/buildings.



## **Routine monitoring**

Regular and proactive monitoring of weaner pigs, including carefully observing their behavior, is essential for ensuring their health and optimizing growth performance. By implementing effective monitoring strategies, producers can identify potential challenges early and take timely interventions to minimize negative impacts.

## **Pig positive people**

Dr. Parke emphasized that the attitude and skills of stockpersons play a significant role in reducing stress during this vulnerable weaning transition period. Positive handling can improve piglet welfare and their future response to human contact, which is crucial for their short and long-term production performance.

Piglets that receive positive handling are likelier to demonstrate affiliative behaviors towards humans, facilitating smoother transitions during weaning and enhancing their overall development. Stockpersons should be trained to recognize signs of stress or discomfort in pigs.

## **Collaborative approach**

“Collaboration is critical for successful weaning; we can’t have silos in pig production unless it’s to store feed,” joked Dr. Parke. “By adopting a proactive approach that emphasizes collaboration and comprehensive management strategies across the production system, pig welfare and long-term productivity of the herd will be enhanced,” she concluded.

EW Nutrition’s Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Merideth Parke, Global Application Manager, Swine, was one of the highly experienced speakers of EW Nutrition. She is a veterinarian who strongly focuses on swine health and preventive medicine.

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# **Successful weaning requires adequate pre-weaning preparation**



#### *Conference report*

The abrupt transition from the sow's milk to solid feed, combined with environmental changes and social restructuring, creates a challenging situation for young piglets. Weaning is a critical phase that subjects piglets to multiple stressors, which can have cumulative effects on their health and development. Weaning stressors are inevitable in the piglets' development; however, effective pre-weaning management practices can significantly minimize their impact on health and performance.

## **Pre-weaning measures help improve weaner performance.**

"Successful weaning of piglets is a multifaceted process that requires careful management and strategic planning well before the actual weaning event," says Dr. Merideth Parke, Global Application Manager, Swine, EW Nutrition. She emphasized the following key pre-weaning factors that can significantly influence success during this most critical time.

### **Genetics**

Selecting the right genetics for your specific production system is crucial for ensuring successful weaning outcomes. The genetic traits of sows with a direct impact include sow resilience, litter size, piglet birth weights, and overall growth rates.

Furthermore, it is decisive for piglets' survival and performance that the sow shows strong maternal instincts, and, to ensure enhanced colostrum and milk uptake, an adequate number of functional teats and high milk production.

# Gestation and farrowing influencers

Having an optimal body condition score at farrowing is essential for sows. Being overweight or underweight poses the risk of prolonged farrowing and reduced colostrum and milk production.

On the piglet side, prolonged farrowing negatively impacts their vitality at birth, which correlates with reduced colostrum uptake and increased pre-weaning mortality rates.

## Environmental conditions

Newborn piglets are particularly vulnerable to hypothermia and have a minimal critical temperature of 33-35°C. Below this range, they struggle to maintain their body temperature, which can lead to increased mortality rates. Cold piglets are less likely to suckle, compromising their energy reserves and ability to maintain body temperature.

In contrast, lactating sows have an optimal temperature of 18-22°C to maximize feed intake and milk production. Therefore, to balance the temperature needs of sow and piglets, it is essential to create a controlled temperature, draft-free creep microenvironment for piglets.

## Hygiene

The hygiene of farrowing crates plays an essential role in the successful weaning of piglets. Maintaining a clean environment significantly impacts the health and growth of piglets, ultimately influencing their survival and weight at weaning. "We must consider the time spent cleaning, disinfecting, and drying farrowing crates an investment, not a cost," emphasized Dr. Parke. "Doing these routine tasks really well will inevitably reduce the time spent treating sick pigs."

## Lactation phase

The primary objective of pre-weaning measures is to ensure adequate colostrum and milk production throughout lactation while beginning the adjustment to solid feed. Efforts should be directed toward facilitating nursing access for all piglets, with particular attention to smaller or weaker ones probably facing difficulties accessing teats.

Split suckling can be the method of choice for improving their colostrum and milk intake, particularly in large litters. For that measure, larger, more robust piglets are separated, allowing smaller or weaker piglets to nurse first. Once the weaker piglets have had sufficient time, the groups are swapped.

However, according to Dr. Parke, fostering piglets is recommended to be undertaken cautiously. "While it can be beneficial, it can significantly disrupt pathogen stability and teat hierarchy, particularly when it occurs after the first 24-48 hours of birth when piglets have established their preference for specific teats. This can increase fighting among piglets as they establish a new hierarchy. This aggression can result in injuries, especially for weaker or smaller piglets. Fighting can also cause damage to the sow's udder, leading to infections or mastitis, compromising milk production and overall sow health," she stated.

## Nurturing the gut

Providing creep feed for a minimum of 7 days before weaning significantly boosts litter weight at weaning and reduces the risk of post-weaning fallback. Early exposure to solid feed accelerates the development of digestive enzymes and acid production, both essential for breaking down carbohydrates and proteins.

Combining pre-weaning creep feeding with high-quality, palatable post-weaning diets has been shown to lead to piglets with increased post-weaning feed intake, health, and growth during the critical post-weaning transition.

As the swine sector evolves with larger litter sizes and, therefore, increased competition for sows' milk, using milk replacers is becoming common practice. Following a "little and often" approach by providing small amounts of fresh milk replacer multiple times a day is most effective. The hygienic preparation and feeding of milk replacers go without saying to prevent the growth of harmful bacteria and molds that can lead to diarrhea and other health issues in piglets.



## Collaborative approach

The swine industry is grappling with mounting challenges associated with post-weaning stress and health, exacerbated by the prohibition of AGPs and the use of pharmacological levels of dietary zinc and copper in many regions. Addressing these issues requires a coordinated strategy to improve piglet welfare and optimize production outcomes. "By adopting a proactive approach emphasizing collaboration and comprehensive management strategies across the production system, piglet welfare and long-term productivity can be enhanced," concluded Dr. Parke.

EW Nutrition's Swine Academy took place in Ho Chi Minh City and Bangkok in October 2024. Dr. Merideth Parke, Global Application Manager, Swine, was one of the highly experienced speakers of EW Nutrition. She is a veterinarian who strongly focuses on swine health and preventive medicine.

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## Piglet rearing - there is still room for improvement!





By **I. Heinzl**, Editor, and **Predrag Persak**, Regional Technical Manager North Europe

Optimal rearing conditions for piglets are crucial for ensuring their healthy growth, reducing mortality, and enhancing productivity. These conditions include proper temperature, nutrition, housing, hygiene, and care. Here are the key aspects:

## 1. Temperature and ventilation

Piglets are sensitive to cold because they cannot regulate their body temperature effectively in the first few days after birth. Proper temperature control is essential to prevent chilling, possibly leading to illness and death. Additionally, regulating the temperature would cost energy, which otherwise could be spent for growth.

Signs of a too-cold environmental temperature are piling on top of one another, tucking the legs under the body, being unable to get up, laying near a corner or wall, or shivering, which may stop if the conditions worsen. Measuring the body temperature shows less than 35°C in the case of chilling.

The following temperatures are recommended for successful piglet rearing:

|                               |                                                                                                 |
|-------------------------------|-------------------------------------------------------------------------------------------------|
| Farrowing unit (for newborns) | 32 – 35°C (90–95°F) during the first few days                                                   |
| After the first week          | The temperature can gradually decrease by about 1.5-2.0°C per week until it reaches 25°C (77°F) |

For supplemental heating, heat lamps, heated floors, or creep areas (a designated warm spot) can be used to maintain the ideal temperature, especially in cooler climates.

Temperature is often closely related to ventilation. Ventilation is essential to reduce dust, humidity, ammonia, and other harmful substances occurring in the air. However, if fresh/cold air enters the pigsty, the temperature decreases, which can get dangerous for the piglets. Suitable ventilation means finding a good balance between providing fresh air and maintaining temperature to prevent energy losses and chilling of the piglets.

Comfort zones can be a solution. They are an effective way to keep the piglets warm and ventilation rates

where needed to maintain proper air exchange and humidity levels.

## 2. Nutrition

Nutrition is critical for piglet growth and immune system development. Most important after birth is the access to colostrum. Piglets are born with an immature immune system, and the maternal antibodies ingested with the colostrum are vital for their survival. They should consume colostrum within the first 6 hours after birth.

It will take 5 to 7 days for piglets to stabilize and get regular on suckling schedule.

At around seven days of age, it is recommended to introduce a highly digestible, nutrient-dense creep feed that helps transition piglets from milk to solid food. Fresh and clean water of the best quality must always be available.

Never forget most important nutrient, beside sow's love and care – water. Allow piglets free access to the excellent quality water.

## 3. Housing and Space

A well-designed, clean, and dry environment is critical for reducing stress and promoting health. Farrowing crates help prevent sows from accidentally crushing the piglets during the first few weeks. However, these farrowing crates should provide enough space for the sow to nurse the piglets while allowing piglets to move freely.

Separate warm and clean areas (creep spaces) for the piglets within the farrowing pen are helpful to help the piglets escape from cooler or potentially dangerous parts of the crate. Straw, sawdust, or rubber mats should be provided to keep the piglets warm and comfortable, and good drainage is essential to maintain dryness.

## 4. Hygiene and Health

**Hygiene** is crucial to prevent disease and promote the health of piglets. For this purpose, pens and farrowing units should be thoroughly cleaned. Regular removal of waste and keeping bedding dry helps control pathogens. It is essential to clean and disinfect the farrowing unit from one farrowing to the other to reduce disease risks.

**Health:** After birth, the piglets' umbilical cord stump should be disinfected to prevent infections. A further essential precautionary measure to prevent anemia is an oral supplementation or an iron injection within the first three days of life, as piglets are born with low iron levels.

For further health monitoring and management, it should be ensured that the piglets are vaccinated against common diseases, such as E. coli, Mycoplasma, and Porcine Circovirus. Additionally, deworming protocols and monitoring for signs of parasites should be implemented for parasite control.

## 5. Weaning Practices

Piglets are typically weaned between 3 and 4 weeks of age, but early weaning (around 21 days) can be practiced in intensive systems. Optimal weaning requires gradual adaptation to solid feed and a stress-free environment.

If the piglets are weaned at 21 to 28 days, a high-quality starter diet after weaning is essential to maintain growth rates and minimize post-weaning stress.

## 6. Minimizing Stress

Stress management is essential to prevent disease and poor growth. For this purpose, minimize handling to the minimum during the first few days and, if necessary, handle the piglets gently to reduce stress.

A new environment also means strain for the piglets, so keep the litter groups together during weaning to reduce fighting and social stress.

## 7. Supportive functional feed ingredients

Depending on veterinary and managing practices, the availability of feed, and the possible use of antimicrobials or other medicals as prophylactics, there can be high variability in rearing conditions in diverse areas of the world. In the following, two functional feed ingredients with entirely different modes of action are presented that support piglets at different rearing conditions.

### 7.1 Egg immunoglobulins (IgY) support piglets under poor rearing conditions

Egg immunoglobulins are beneficial if piglets are not raised under the best conditions, meaning lower hygienic standards and higher pathogenic pressure. With egg immunoglobulins coming from hens having been in contact with pathogens relevant to piglets, it is possible to support the young animals. What is the background? Hens are able to transfer maternal antibodies against diseases that they are confronted with to the egg. With this mechanism, they can provide their progeny with a starter kit for the first time after hatching. However, the best thing is that these antibodies are also helpful for mammals.

A trial conducted on a commercial farm in Spain shows the weight development of piglets fed an IgY-containing egg powder product (EP) compared to a negative control. The weaned piglets were fed a two-phase feeding (15 days prestarter, 22 days starter). The control (n=51) received no additional functional feed ingredient, whereas the EP group was fed 2 kg of the product/t of feed during the prestarter phase. The animals were weighed individually on days 16 and 37.

The results are shown in Figures 1 and 2.

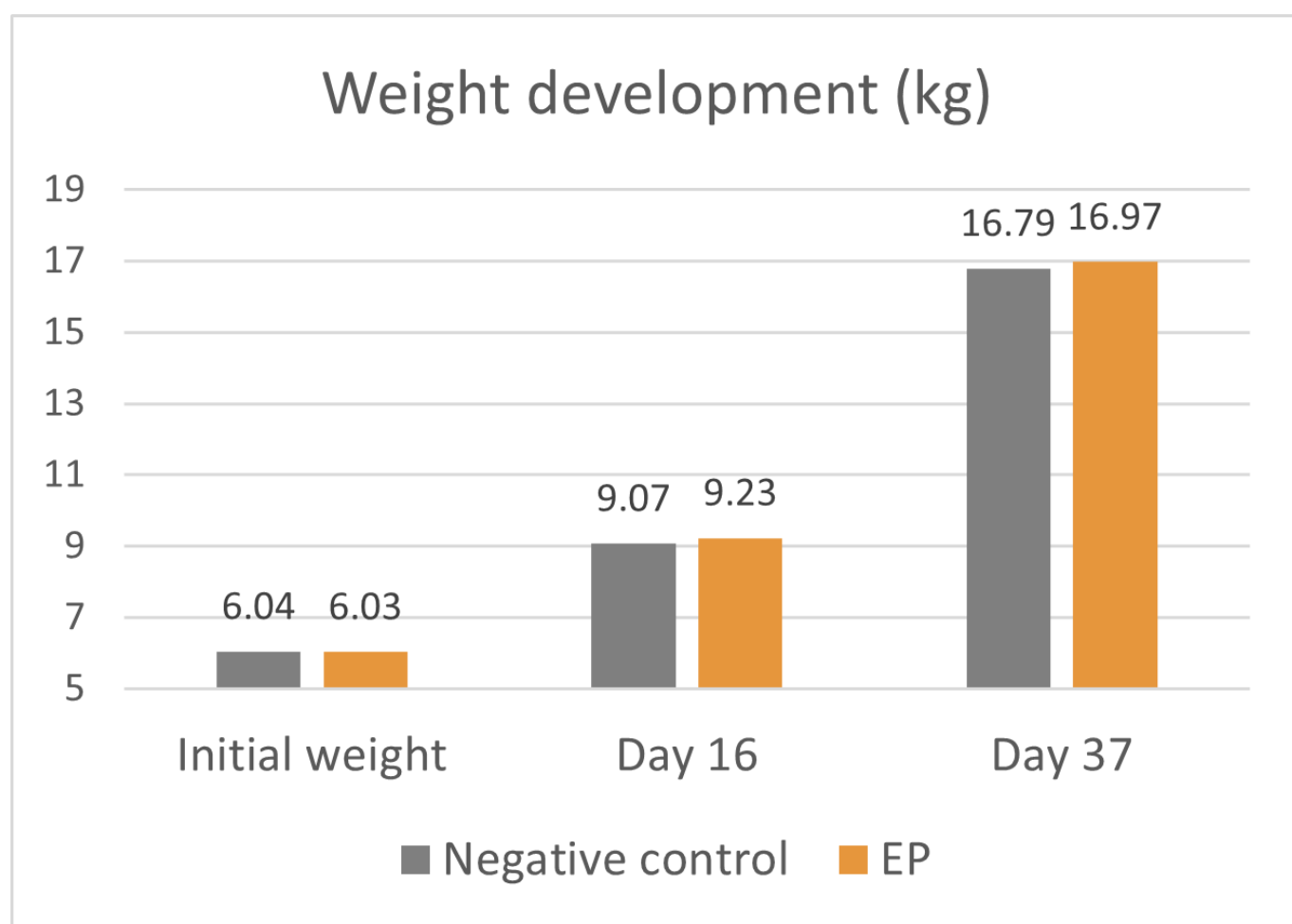


Figure 1: Weight development of piglets receiving an IgY-containing egg powder product compared to a negative control

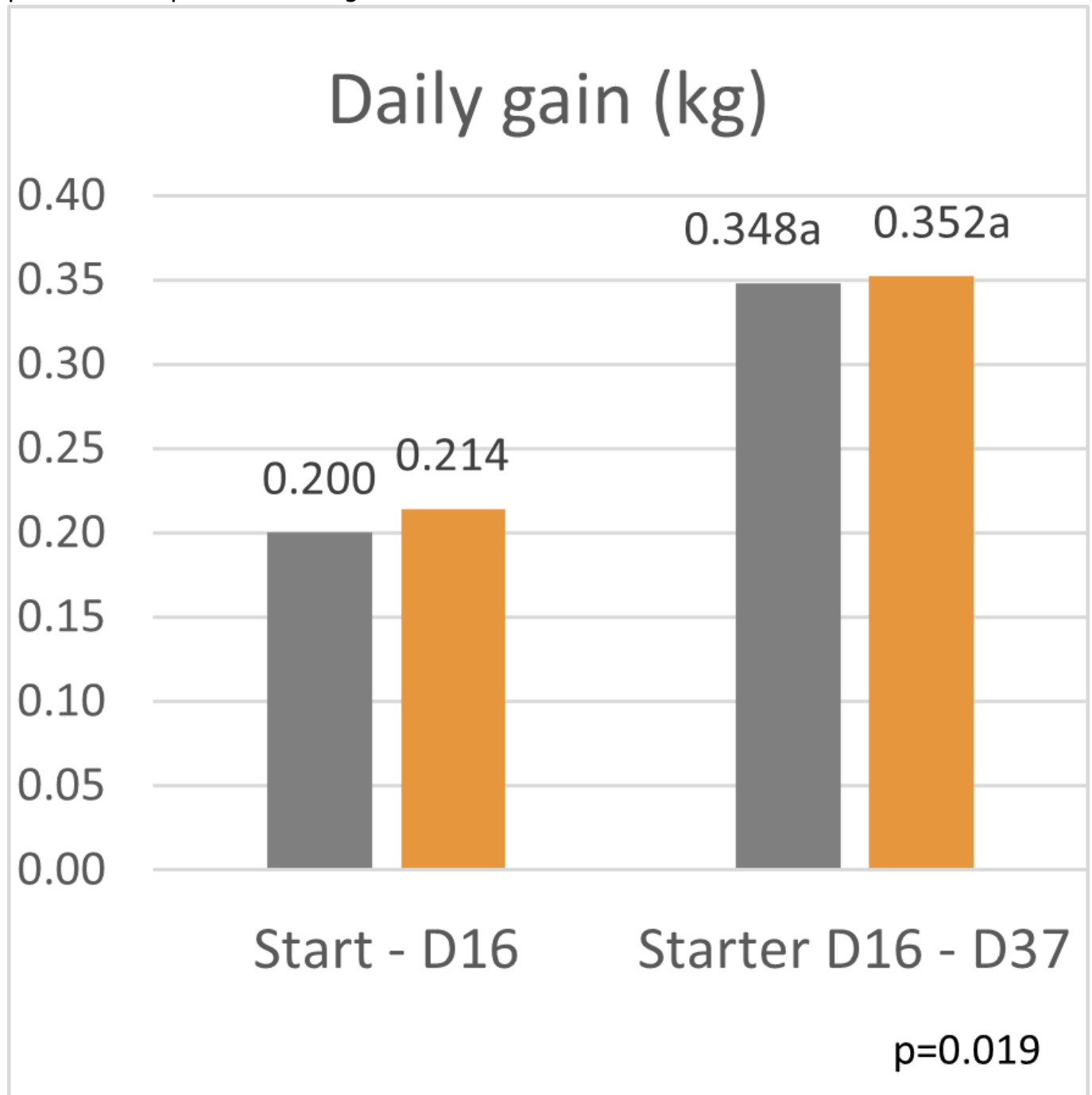


Figure 2: Daily gain of piglets receiving an IgY-containing egg powder product compared to a negative control

**Explanation of the results:** Under poor hygienic conditions, the pathogenic pressure is relatively high, and everything lowering this pressure helps to improve gut health, the utilization of nutrients, and performance. Egg immunoglobulins positively influence the gut microbiome, thus helping reduce diarrhea. By lowering the pathogenic pressure, the organism's energy can be used for growth and must not be employed for the body's defense.

## 7.2 Phytomolecules can even show improvement under optimum conditions

Phytomolecules generally show diverse gut health-promoting effects, from driving the intestinal microbiome in the right direction and strengthening the intestinal barrier to acting as antioxidants or anti-



inflammatories or increasing the secretion of digestive juices and, therefore, improving digestion. Which mode of action is relevant if the piglets are raised under already optimal conditions (best hygiene, no prophylactic antibiotics or zinc oxide) and show the highest growth? Is there still room for improvement? Yes, it is. A trial conducted in Germany adduces evidence.

In this trial, 220 piglets weaned on average at 26 days and weighing around 8 kg were housed in 20 pens of 11 castrated males or gilts each. Piglets were blocked by body weight and fed a two-phase feeding program (phase 1 from day 1 to day 13 and phase 2 from day 17 to day 40; pelleted diet). Neither feed or water medication nor therapeutic levels of ZnO were used.

The results of this piglet trial can be seen in Figures 3 and 4.

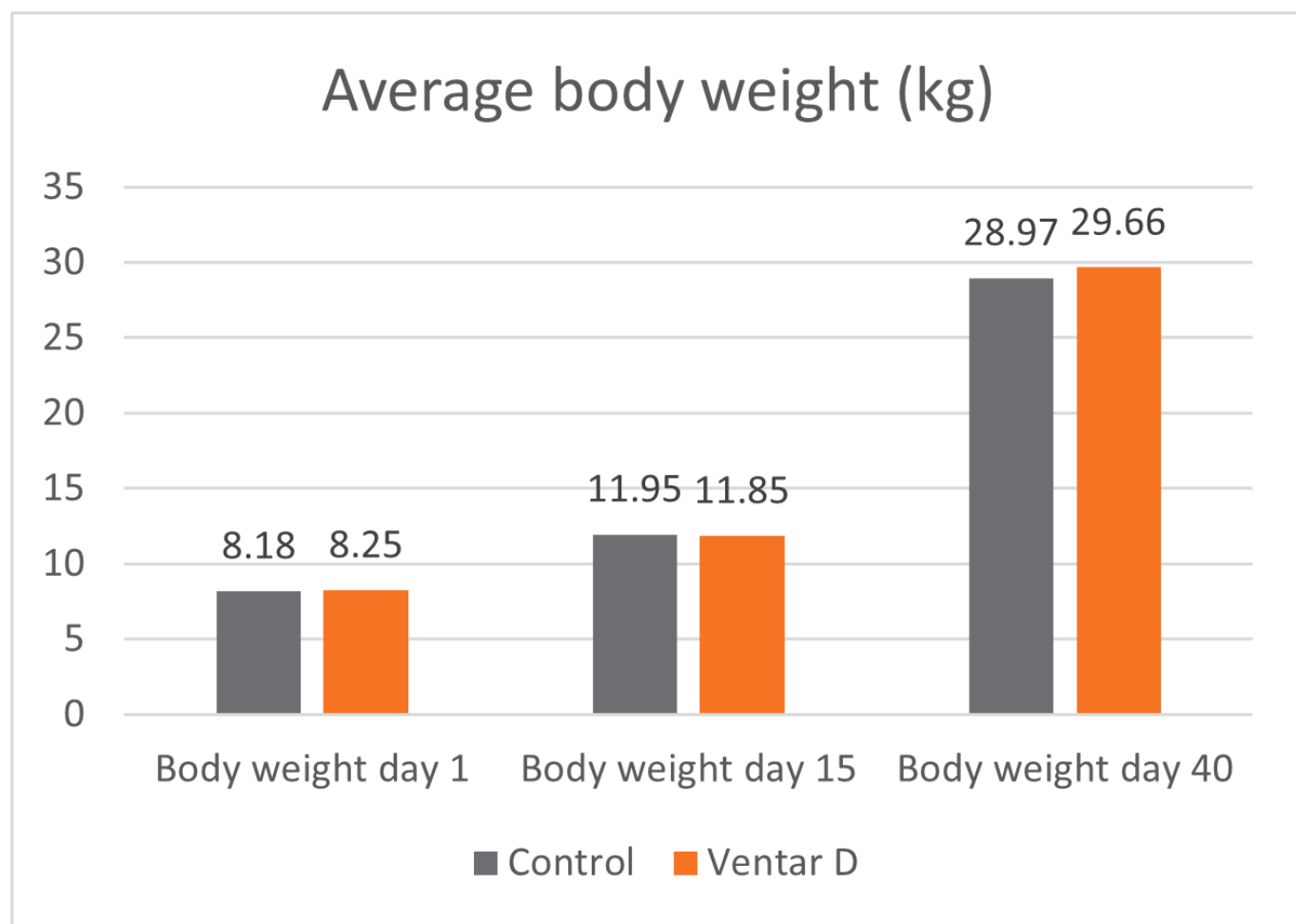


Figure 3: Weight development of piglets fed Ventar D compared to a negative control

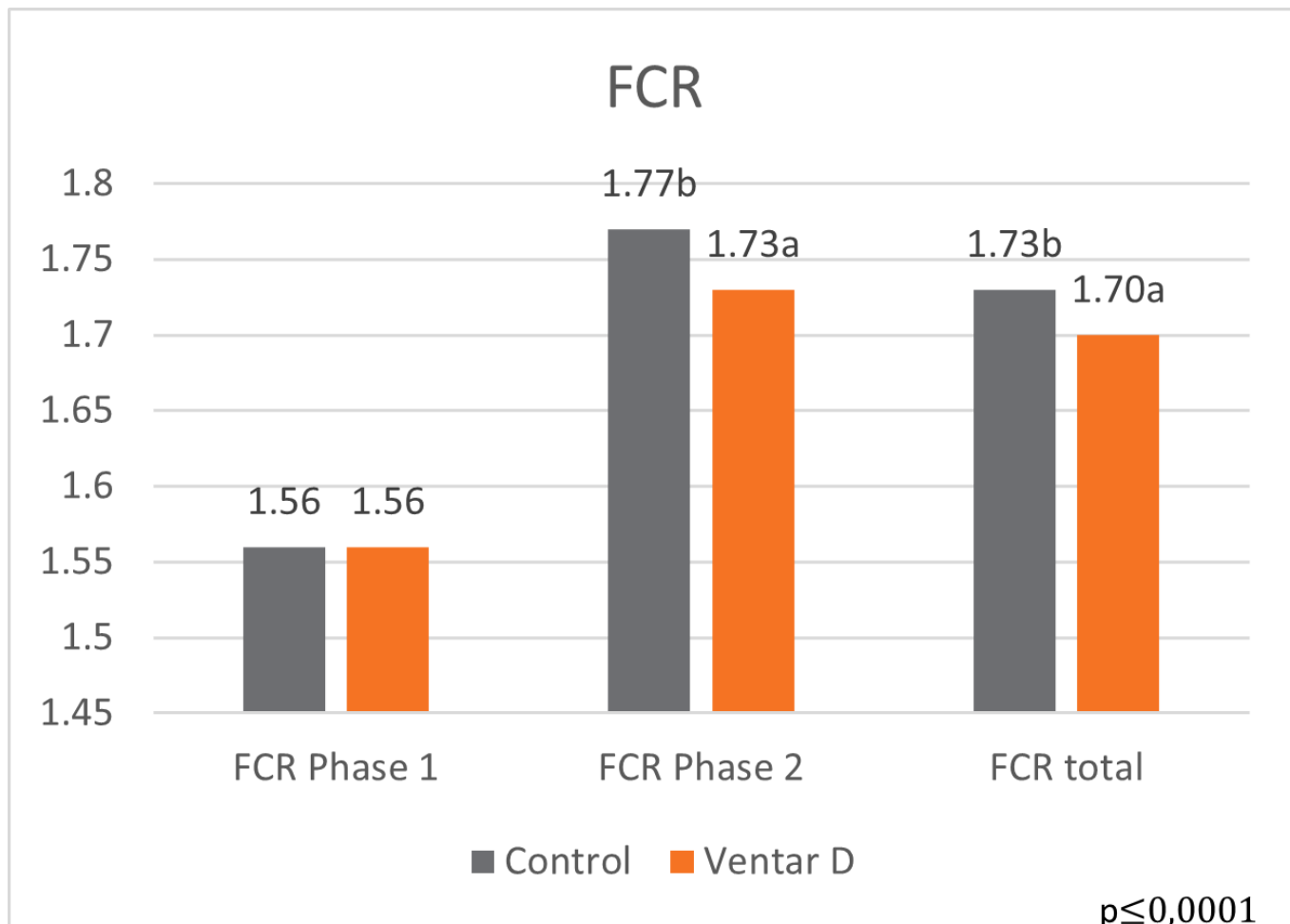


Figure 4: Feed conversion rate in piglets fed Ventar D compared to a negative control

**Explanation of the results:** The figures show that the piglets in the control already have an extremely high weight compared to those of a similar age in the previous trial, indicating the best rearing conditions in this trial. But, even here, Ventar D has the capacity to improve performance. Why? High-performing animals stress their body more than low-performing ones. Anabolic processes increase oxidative stress and non-infectious inflammation and burden the immune system. The relevant mode of action of Ventar D is not the gut health-promoting or the antimicrobial one because there is no issue. The relevant modes of action in this case are antioxidant and anti-inflammatory. With these two characteristics, Ventar D still has the capacity to improve the performance of piglets that are already at the top level.

## 8. Conclusion

For high piglet performance, providing the best possible rearing conditions is essential. However, there are differences concerning these conditions in different areas of the world. Depending on them, different feed strategies can be used. Egg immunoglobulins show the best effects if there is a certain pathogenic pressure. Phytomolecules, however, due to their various modes of action, can be beneficial under different levels in rearing conditions. In a low standard, the antimicrobial and gut health-promoting effect is more relevant; in the case of best conditions, the anti-oxidant and anti-inflammatory effects are decisive.

In summary, it could be said that functional feed ingredients have significant advantages in piglet rearing, but the right choice must be made depending on the prevailing conditions.

# Organic acids can play a crucial role in zinc oxide replacement



*Dr. Inge Heinzl, Editor EW Nutrition &  
Juan Antonio Mesonero Escuredo, GTM Swine/GPM Organic Acids EW Nutrition*

The use of high levels of Zinc Oxide (ZnO) in the EU before 2022 was one of the most common methods to prevent postweaning diarrhea (PWD) in pig production. Pharmacologically high levels of ZnO (2000-3000 ppm) increase growth and reduce the incidence of enteric bacterial diseases such as post-weaning diarrhea (PWD) ([Carlson et al., 1999](#); [Hill et al., 2000](#); [Hill et al., 2001](#); [Poulsen & Larsen, 1995](#); [De Mille et al., 2019](#)).

However, ZnO showed adverse effects, such as the accumulation of heavy metal in the environment, the risk for antimicrobial resistance (AMR), and problems of mineral toxicity and adverse growth effects when feeding it longer than 28 days ([Jensen et al., 2018](#); [Cavaco et al., 2011](#); [Vahjen, 2015](#); [Romeo et al., 2014](#); [Burrough et al., 2019](#)). To replace ZnO in pig production, let us first look at its positive effects to know what we must compensate for.

## ZnO has a multifactorial mode of action

ZnO shows several beneficial characteristics that positively influence gut health, the immune system, digestion, and, therefore, also overall health and growth performance.

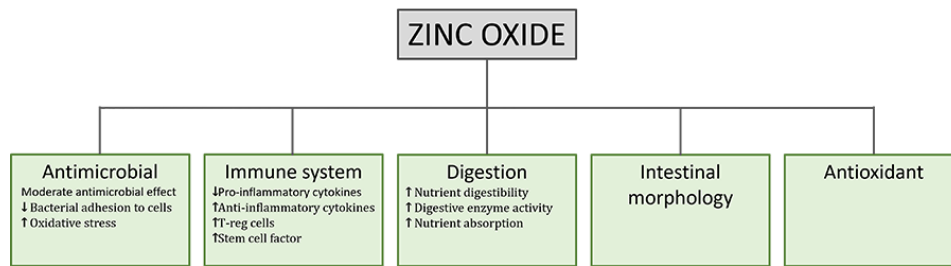


Figure 1. Beneficial effects and ZnO mode of action in postweaning piglets

## 1. ZnO acts as an antimicrobial

Concerning the antimicrobial effects of ZnO, different possible modes of action are discussed:

- ZnO in high dosages generates reactive oxygen species (ROS) that can damage the bacterial cell walls ([Pasquet et al., 2014](#))
- The death of the bacterial cell due to direct contact of the metallic Zn to the cell ([Shearier et al., 2016](#))
- Intrinsic antimicrobial properties of the  $\text{ZnO}^{2+}$  ions after dissociation. The uptake of zinc into cells is regulated by homeostasis. A concentration of the  $\text{ZnO}^{2+}$  ions higher than the optimal level of  $10^{-7}$  to  $10^{-5}$  M (depending on the microbial strain) allows the invasion of  $\text{Zn}^{2+}$  ions into the cell, and the zinc starts to be cytotoxic ([Sugarman, 1983](#); [Borovanský et al., 1989](#)).

ZnO shows activity against, e.g., *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *E. coli*, *Streptococcus pyogenes*, and other enterobacteria (Ann et al., 2014; Vahjen et al., 2016). However, Roselli et al. (2003) did not see a viability-decreasing effect of ZnO on ETEC.

## 2. ZnO modulates the immune system

Besides fighting pathogenic organisms as described in the previous chapter and supporting the immune system, ZnO is an essential trace element and has a vital role in the immune system. ZnO improves the innate immune response, increasing phagocytosis and oxidative bursts from macrophages and neutrophils. It also ameliorates the adaptative immune response by increasing the number of T lymphocytes (T cells) in general and regulatory T lymphocytes (T-regs) in particular. These cells control the immune response and inflammation ([Kloubert et al., 2018](#)). Macrophage capacity for phagocytosis ([Ercan and Bor, 1991](#)) and to kill parasites ([Wirth et al., 1989](#)), and also the killing activity of natural killer cells depends on Zn ([Rolles et al., 2018](#)). By reducing bacterial adhesion and blocking bacterial invasion, ZnO disburdens the immune system ([Roselli et al., 2003](#)).

ZnO reduces the expression of several proinflammatory cytokines induced by ETEC ([Roselli et al., 2003](#)). Several studies have also shown a modulation effect on intestinal inflammation, decreasing levels of IFN- $\gamma$ , TNF- $\alpha$ , IL-1 $\beta$  and IL-6, all pro-inflammatory, in piglets supplemented with ZnO ([Zhu et al., 2017](#); [Grilli et al., 2015](#)).

## 3. ZnO improves digestion and promotes growth

Besides protecting young piglets against diarrhea, the goal is to make them grow optimally. For this target, an efficient digestion and a high absorption of nutrients is essential. Stimulating diverse pancreatic enzymes such as amylase, carboxypeptidase A, trypsin, chymotrypsin, and lipase increases digestibility ([Hedemann et al., 2006](#); [Pieper et al., 2015](#)). However, Pieper et al. (2015) also showed that a long-term supply of very high dietary zinc triggers oxidative stress in the pancreas of piglets.

By stimulating the secretion of ghrelin at the stomach level and thereby promoting the release of insulin-like growth factor (IGF-1) and cholecystokinin (CCK), ZnO enhances muscle protein synthesis, cell



proliferation, and feed intake ([Yin et al., 2009](#); [MacDonald et al., 2000](#))).

The result of improved digestion is increased body weight and average daily gain, which can be seen, e.g., in a study by [Zhu et al. \(2017\)](#).

## 4. ZnO protects the intestinal morphology

ZnO prevents the decrease of the trans-endothelial electrical resistance (TEER), usually occurring in the case of inflammation, by downregulating TNF- $\alpha$  and IFN- $\gamma$ . TNF- $\alpha$ , as well as IFN- $\gamma$ , increase the permeability of the epithelial tight junctions and, therefore, the intestinal barrier ([Al-Sadi et al., 2009](#)).

The enterotrophic and anti-apoptotic effect of ZnO is reflected by a higher number of proliferating and PCNA-positive cells and an increased mucosa surface in the ileum (higher villi, higher villi/crypt ratio) ([Grilli et al., 2015](#)). [Zhu et al. \(2017\)](#) also saw an increase in villus height in the duodenum and ileum and a decrease in crypt depth in the duodenum due to the application of 3000 mg of ZnO/kg. Additionally, they could notice a significant ( $P < 0.05$ ) upregulation of the mRNA expression of the zonula occludens-1 and occluding in the mucosa of the jejunum of weaned piglets.

In a trial conducted by [Roselli et al. \(2003\)](#), the supplementation of 0.2 mmol/L ZnO prevented the disruption of the membrane integrity when human Caco-2 enterocytes were challenged with ETEC.

## 5. ZnO acts antioxidant

The antioxidant effect of ZnO was shown in a study conducted by [Zhu et al., 2017](#). They could demonstrate that the concentration of malondialdehyde (MDA), a marker for lipid peroxidation, decreased on day 14 or 28, and the total concentration of superoxide dismutase (SOD), comprising enzymes that transform harmful superoxide anions into hydrogen peroxide, increased on day 14 ( $P < 0.05$ ). Additionally, Zn is an essential ion for the catalytic action of these enzymes.

# Which positive effects of ZnO can be covered by organic acids (OAs)?

## 1. OAs act antimicrobial

OAs, on the one hand, lower the pH in the gastrointestinal tract. Some pathogenic bacteria are susceptible to low pH. At a pH  $< 5$ , the proliferation of, e.g., Salmonella, E. coli, and Clostridium is minimized. The good thing is that some beneficial bacteria, such as lactobacilli or bifidobacteria, survive as they are acid-tolerant. The lactobacilli, on their side, can produce hydrogen peroxide, which inhibits, e.g., Staphylococcus aureus or Pseudomonas spp. ([Juven and Pierson, 1996](#)).

Besides this more indirect mode of action, a more direct one is also possible: Owing to their lipophilic character, the undissociated form of OAs can pass the bacterial membrane ([Partanen and Mroz, 1999](#)). The lower the external pH, the more undissociated acid is available for invading the microbial cells. Inside the cell, the pH is higher than outside, and the OA dissociates. The release of hydrogen ions leads to a decrease in the internal pH of the cell and to a depressed cell metabolism. To get back to "normal conditions", the cell expels protons. However, this is an energy-consuming process; longer exposure to OAs leads to cell death. The anion remaining in the cell, when removing the protons, disturbs the cell's metabolic processes and participates in killing the bacterium.

These theoretical effects could be shown in a practical trial by [Ahmed et al. \(2014\)](#). He fed citric acid (0.5 %) and a blend of acidifiers composed of formic, propionic, lactic, and phosphoric acid + SiO<sub>2</sub> (0.4 %) and saw a reduction in fecal counts of Salmonella and E. coli for both groups.

## 2. OAs modulate the immune system

The immune system is essential in the pig's life, especially around weaning. Organic acids have been shown to support or stimulate the immune system. Citric acid (0.5%), as well as the blend of acidifiers mentioned before (Ahmed et al., 2014), significantly increased the level of serum IgG. IgG is part of the humoral immune system. They mark foreign substances to be eliminated by other defense systems.

[Ren et al.](#) (2019) could demonstrate a decrease in plasma tumor necrosis factor- $\alpha$  that regulates the activity of diverse immune cells. He also found lower interferon- $\gamma$  and interleukin (IL)-1 $\beta$  values in the OA group than in the control group after the challenge with ETEC. This trial shows that inflammatory response can be mitigated through the addition of organic acids.

## 3. OAs improve digestion and promote growth

In piglets, the acidity in the stomach is responsible for the activation and stimulation of certain enzymes. Additionally, it keeps the feed in the stomach for a longer time. Both effects lead to better digestion of the feed.

In the stomach, the conversion of pepsinogen to pepsin, which is responsible for protein digestion, is catalyzed under acid conditions ([Sanny et al., 1975](#)) group. Pepsin works optimally at two pH levels: pH 2 and pH 3.5 ([Taylor, 1959](#)). With increasing pH, the activity decreases; at pH 6, it stops. Therefore, a high pH can lead to poor digestion and undigested protein arriving in the intestine.

These final products of pepsin protein digestion are needed in the lower parts of the GIT to stimulate the secretion of pancreatic proteolytic enzymes. If they do not arrive, the enzymes are not activated, and the inadequate protein digestion continues. Additionally, gastric acid is the primary stimulant for bicarbonate secretion in the pancreas, neutralizing gastric acid and providing an optimal pH environment for the digestive enzymes working in the duodenum.

As already mentioned, the pH in the stomach influences the transport of digesta. The amount of digesta being transferred from the stomach to the small intestine is related to the acidity of the chyme leaving the stomach and arriving in the small intestine. Emptying of the stomach can only take place when the duodenal chyme can be neutralized by pancreatic or other secretions ([Pohl et al., 2008](#)); so, acid-sensitive receptors provide feedback regulation and a higher pH in the stomach leads to a faster transport of the digesta and a worse feed digestion.

## 4. OAs protect the intestinal morphology

Maintaining an intact gut mucosa with a high surface area is crucial for optimal nutrient absorption. Research suggests organic acids play a significant role in improving mucosal health:

Butyric acid promotes epithelial cell proliferation, as demonstrated in an *in vitro* pig hindgut mucosa study ([Sakata et al., 1995](#)). Fumaric acid, serving as an energy source, may locally enhance small intestinal mucosal growth, aiding in post-weaning epithelial cells' recovery and increasing absorptive surface and digestive capacity ([Blank et al., 1999](#)). Sodium butyrate supplementation at low doses influences gastric morphology and function, thickening the stomach mucosa and enhancing mucosal maturation and differentiation ([Mazzoni et al., 2008](#)).

Studies show that organic acids affect gut morphology, with a mixture of short-chain and mid-chain fatty acids leading to longer villi ([Ferrara et al., 2016](#)) and Na-butyrate supplementation increasing crypt depth and villi length in the distal jejunum and ileum ([Kotunia et al., 2004](#)). However, the villi length and mucosa thickness in the duodenum were reduced. Dietary sodium butyrate has been linked to increased microvilli length and cecal crypt depth in pigs ([Gálfi and Bokori, 1990](#)).

## 5. OAs show antioxidant activity

The last characteristic, the antioxidant effect, cannot be provided at the same level as with ZnO; however, [Zhang et al. \(2019\)](#) attest to OAs a certain antioxidant activity. Oxalic, citric, acetic, malic, and succinic acids, which were extracted from *Camellia oleifera*, also showed good antioxidant activity in a trial conducted by [Zhang et al. \(2020\)](#).

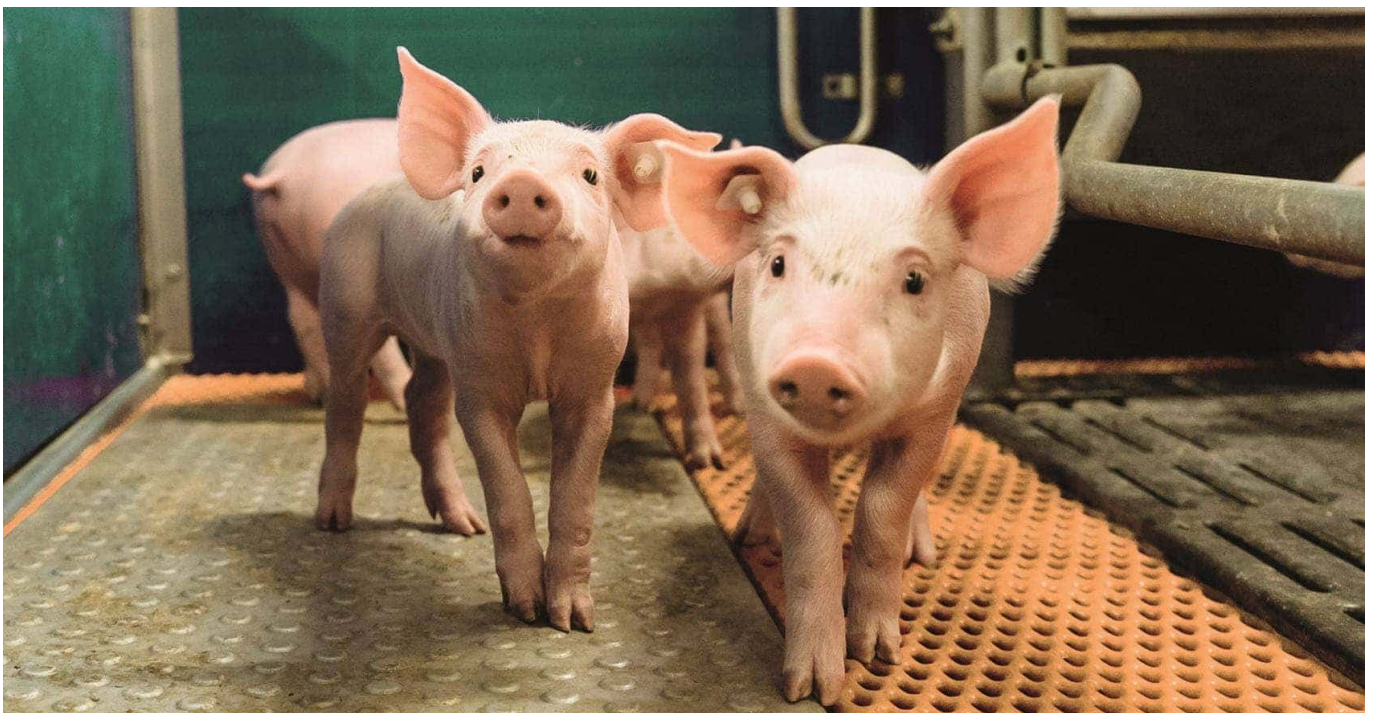
## Organic acids are an excellent tool to compensate for the ban on ZnO

The article shows that organic acids have similar positive effects as zinc oxide. They act antimicrobial, modulate the immune system, maintain the gut morphology, fight pathogenic microbes, and also act – slightly – antioxidant. Additionally, they have a significant advantage: they are not harmful to the environment. Organic acids used in the proper pH range and combination are good tools for replacing zinc oxide.

References on request

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## Acidifiers support piglets after weaning



By **Dr. Inge Heinzl**, Editor, EW Nutrition

**In piglet production, high productivity, meaning high numbers of healthy and well-performing**

**piglets weaned per sow and year, is the primary target. Diarrhea around weaning often gets in the way of achieving this goal.**

Up to the ban of antibiotic growth promoters in 2006, antibiotics were often applied prophylactically to help piglets overcome this critical time. Zinc oxide (ZnO) application is another measure that cannot be used anymore to prevent piglet diarrhea. Effective alternatives are required.

## Weaning - a critical point in piglets' life

Weaning stress is well-known to have a negative impact on the balance of the intestinal microflora and gastrointestinal functions ([Miller et al., 1985](#)). Suckling piglets have a limited ability to produce hydrochloric acid, but nature has a solution to compensate for this inadequacy. The lactobacilli present in the stomach can use the lactose in the sow's milk to produce lactic acid ([Easter, 1988](#)). In nature, the piglets would start to eat small amounts of solid feed at about three weeks when the sow's milk production no longer covers their nutrient demand. By increasing the feed intake, the piglets stimulate hydrogen chloride (HCl) production in their stomachs.

In piglet production, where weaning occurs at three or four weeks of age, the piglets are still not eating considerable amounts of solid feed. It is often the case that 50 % of the piglets take feed at the earliest after 24 h, and 10 % accept the first feed only after 48 h ([Brooks, 2001](#)). Additionally, hard grains in the diet can physically damage the small intestine wall, reducing villus height and crypt depth ([Kim et al., 2005](#)).

Only a minor production of HCl, no more lactose supply for the lactobacilli, varying feed intake, and high buffering capacity of the feed lead to a pH of >5 in the stomach.

## The higher stomach pH is partly responsible for problems after weaning

A pH higher than 5, besides causing direct effects on the microflora in the stomach, has consequences for the whole digestive tract and digestion.

A high pH is favorable for certain microorganisms, including coliforms (Sissons, 1989) and other acid-sensitive bacteria such as *Salmonella typhimurium*, *Salmonella typhi*, *Campylobacter jejuni*, and *V. cholerae* (Smith, 2003).

### 1. Lower activity of proteolytic enzymes

In the stomach, the conversion of pepsinogen to pepsin, which is responsible for protein digestion, is catalyzed under acid conditions ([Sanny et al., 1975](#)). Pepsin works optimally at two pH levels: pH 2 and pH 3.5 ([Taylor, 1959](#)). With increasing pH, the activity decreases; at pH 6, it stops. Therefore, a high pH can lead to poor digestion and undigested protein arriving in the intestine. There, it can be used as "feed" for harmful bacteria, leading to their proliferation. [Barrow et al. \(1977\)](#) found higher counts of coliforms in piglets' intestinal tract two days after weaning, while the number of lactobacilli was depressed.

In the lower parts of the gastrointestinal tract (GIT), the final products of the pepsin protein digestion are needed to stimulate the secretion of pancreatic proteolytic enzymes. If no final products arrive, the enzymes are not activated, and the inadequate protein digestion continues. Additionally, gastric acid is the main stimulant for bicarbonate secretion in the pancreas, neutralizing gastric acid and providing an optimal pH environment for the digestive enzymes working in the duodenum.

### 2. Expedited digesta transport

The stomach pH also influences the transport of digesta. The acidity of the chyme leaving the stomach and arriving in the small intestine is decisive for the amount of digesta being transferred from the stomach to the small intestine. Acid-sensitive receptors provide feedback



regulation to prevent the stomach from emptying until the duodenal chyme can be neutralized by pancreatic or other secretions ([Pohl et al., 2008](#)). Therefore, a higher pH in the stomach leads to a faster transport of the digesta, resulting in worse feed digestion.

### 3. Proliferation of microorganisms

A high pH is favorable for certain microorganisms, including coliforms ([Sissons, 1989](#)) and other acid-sensitive bacteria such as *Salmonella typhimurium*, *Salmonella typhi*, *Campylobacter jejuni*, and *V. cholerae* ([Smith, 2003](#)).

**Elevated stomach pH + incomplete immune system = diarrhea**

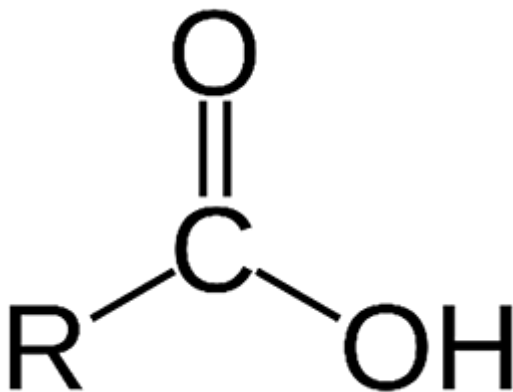
## Acidifiers can mitigate the adverse effects of weaning on piglets

To overcome this critical time of weaning and maintain performance, acidifiers can be a helpful tool. They improve gut health, stimulate immunity, and serve as nutrient sources – while also positively affecting feed and water hygiene.

### What are acidifiers?

Acidifiers' role in pig nutrition has evolved from feed preservatives to stomach pH stabilizers, compensating for young pigs' reduced digestive capacity ([Ferronato and Prandini, 2020](#)). They are now used to replace antibiotic growth promoters and ZnO, which were applied for a long time to mitigate the negative effects of weaning.

In general, both organic and inorganic acids and their salts feature in animal nutrition. They can be added to the feed or the water.



### Organic acids: Commonly used with good results

Feed acidifiers are usually organic acids, including fatty and amino acids. Their carboxyl functional group is responsible for their acidic specificity as feed additives ([Pearlin et al., 2019](#)). Their pKa, the pH where 50 % of the acid occurs in a dissociated form, is decisive for their antimicrobial action. In animal nutrition, acids with pKa 3-5 are typically used ([Kirchgeßner and Roth, 1991](#)).

Organic acids used as feed additives can be divided into three groups:

- Simple monocarboxylic acids such as formic, acetic, propionic, and butyric acid
- Carboxylic acids with a hydroxyl group such as lactic, malic, tartaric, and citric acid

- Short-chain carboxylic acids with double bonds – fumaric and sorbic acid.

The primary acids for pig nutrition are acetic, fumaric, formic, lactic, benzoic, propionic, sorbic, and citric acids ([Roth and Ettle, 2005](#)).

## Inorganic acids - the low-cost version

Inorganic acids are cheaper than organic acids, but their only effect is to decrease the pH. Additionally, they are extremely corrosive and dangerous liquids due to their strong acidity in a pure state ([Kim et al., 2005](#)).

## Salts are easier to handle

The advantage of salts over free acids is that they are generally odorless and easier to handle in the feed manufacturing process due to their solid and less volatile form. Higher solubility in water is a further advantage compared to free acids ([Huyghebaert and Van Immerseel, 2011](#); [Roth and Ettle, 2005](#); [Partanen and Mroz, 1999](#)). The better handling and higher palatability make acid salts a more user-friendly method to apply acids to feed and water without compromising their efficacy ([Luise et al., 2020](#)).

The salts are mainly produced with calcium, potassium, and sodium. They include calcium formate, potassium diformate, sodium diformate, and sodium fumarate.

## Blends

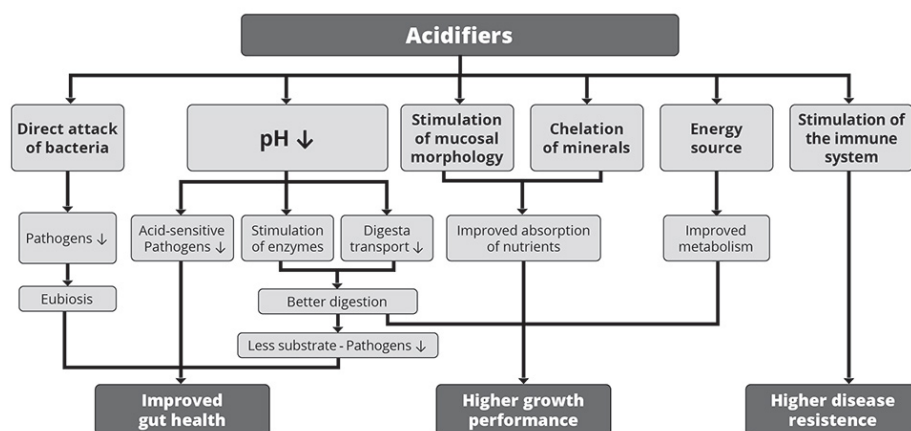
A mixture of diverse acidifiers combines the different characteristics of these substances. Perhaps, there may be synergistic effects. Acid blends are more and more used as feed additives. They have a wider-ranging action than single substances.

[Roth et al.](#) (1996) showed that a combination of formic acid with various formats is more effective than the application of formic acid alone.

## The main effects of acidifiers

Acidifiers support piglets during the critical time after weaning through different modes of action. The final results are:

- Improvement in gut health
- Increase in growth performance
- Stabilization of the immune system.



### 1. Improvement in gut health

As shown in figure 1, the improvement in gut health relies on the antimicrobial effect of organic acids and the decrease in the stomach's pH.

## 1.1 Organic acids directly attack bacteria

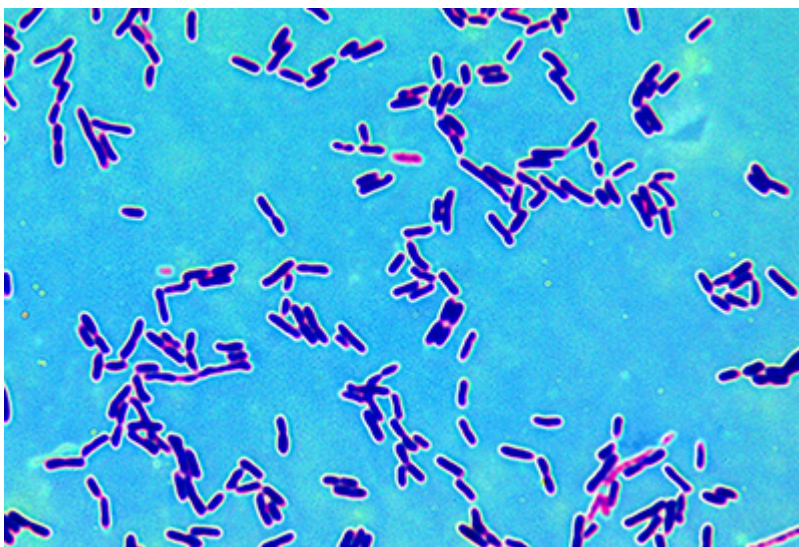
Organic acids not only act through their pH-decreasing effect but also directly attack pathogens. Due to their lipophilic character, organic acids can pass the bacterial cell membrane when they are in their undissociated form ([Partanen in Piva et al., 2001](#)). The lower the external pH, the more undissociated acid can pass the membrane.

Within the cell, the pH is higher. Hence, the organic acid dissociates and releases hydrogen ions, reducing the cytoplasmic pH from alkaline to acid. Cell metabolism is depressed at lower pH. Therefore, the bacterial cell needs to expel protons to get the cytoplasmic pH back to normal. As this is an energy-consuming process, more prolonged exposure to organic acids kills the bacterium. Additionally, the anions staying within the cell disturb the cell's metabolic processes and participate in killing the bacterium.

Studies from [Van Immerseel et al. \(2006\)](#) revealed that many fermentative bacteria could let their intracellular pH decline and prevent increased acid penetration. Bacteria with a neutrophil pH, however, react more sensitively.

## 1.1 Decreased pH reduces non-acid-tolerant pathogens

There is a direct effect of pH on the microflora. Some pathogenic bacteria are susceptible to low pH. The proliferation of, e.g., *E. coli*, *Salmonella*, and *Clostridium perfringens* is minimized at a pH<5. Acid-tolerant bacteria such as lactobacilli or bifidobacteria, however, survive. Many lactobacilli can produce hydrogen peroxide, which inhibits, e.g., *Staphylococcus aureus* or *Pseudomonas* spp. ([Juven and Pierson, 1996](#)).



Already [Fuller \(1977\)](#) showed in *in vitro* experiments that certain bacteria such as Streptococci, Salmonella, and *B. cereus* don't grow in an environment with pH 4.5 or even die (*Micrococcus*). In contrast, *Lactobacilli* are not so susceptible to this low pH. Using the same binding sites as harmful bacteria, they suppress coliforms, for example. [Kirchgeßner et al. \(1997\)](#) found a stronger reduction of *E. coli* than Lactobacilli and Bifidobacteria in different gut segments when exposed to 1.25 % formic acid.

## 1.2 Recovery of eubiosis through reduction of substrate

The reduction of the pH through organic acids maintains or stimulates the secretion of proteolytic enzymes in the stomach (pepsin) and pancreatic enzymes. Additionally, the acid leaving the stomach is partly responsible for regulating gastric emptying ([Ravindran and Kornegay, 1993](#); [Mayer, 1994](#)). Both effects by improving protein digestion, reduce the fermentable substrates arriving in the hindgut. This decreases the quantity of fermentable substrate arriving in the intestine and, therefore, the growth of undesired pathogens.

## 2. Promotion of growth

### 2.1 *Enhanced digestion of macronutrients*

As explained above, the acidity in the stomach is responsible for the activation and stimulation of enzymes. Additionally, the lower pH keeps the feed in the stomach for longer. Both result in better digestion.

The improved utilization of nutrients leads to higher daily gain and better feed conversion. In pigs, the growth-promoting effect of organic acids is particularly pronounced during the first few weeks after weaning ([Roth and Ertle, 2005](#)). Some examples of the growth-promoting effect of formic and propionic acid feature in table 1.

| Acid           | Inclusion | ADG     | Feed intake | FCR     | G/F     | Reference                  |
|----------------|-----------|---------|-------------|---------|---------|----------------------------|
| Formic acid    | 0.13 %    | + 6.0 % | + 3.5 %     | - 2 pts |         | Luise et al. (2017)        |
| Formic acid    | 0.64 %    | + 5.0 % | + 3.7 %     | - 1 pt  |         | Luise et al. (2017)        |
| Propionic acid | 2.00 %    | - 4.4 % | - 11.0 %    |         | + 4 pts | Giesting and Easter (1985) |

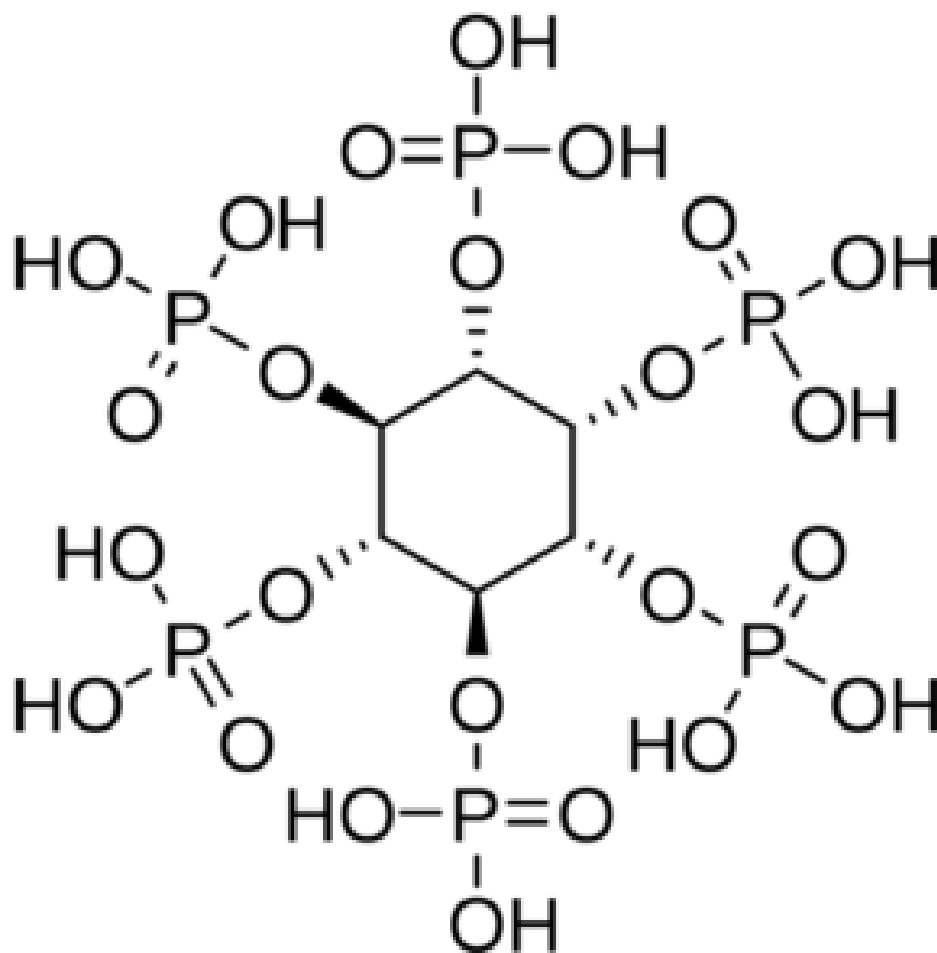
*Table 1: Influence of two commonly used organic acids in animals on growth performance*

Varying results are mainly due to the character of the organic acid, the dosage, the buffering capacity, and the possible reduction of feed intake in case of a high dosage ([Roth and Ertle, 2005](#)).

### 2.2 *Improved utilization of minerals*

Minerals are essential for metabolic processes and, thus, healthy growth. Chelated minerals show a higher digestibility. Acidic anions of the acidifiers form complexes (chelates) with cationic minerals such as Ca, Zn, P, and Mg. The resulting higher digestibility and absorption lead to decreased excretion of supplemented minerals and, therefore, to a lower environmental burden. [Kirchgeßner and Roth \(1982\)](#), e.g., reported an improved absorption and retention of Ca, P, and Zn with the addition of fumaric acid. However, there are also trials showing no effect of acidification of the diet on mineral balance ([Radecki et al., 1988](#)).





*Phytic acid*

Another factor influencing the absorption of minerals, mainly phosphorus, is the amount of intrinsic or microbial phytase in the diet ([Rutherford et al., 2012](#)). The enzyme phytase releases phosphorus out of phytic acid and increases its bioavailability. [Partanen and Mroz](#) (1999) showed that organic acids improve the performance of phytase and, therefore, the bioavailability of phosphorus in the diet.

Besides a better utilization by the animal, improved absorption of minerals means preserving the environment and direct cost-saving, as mineral supplements are expensive.

## **2.3 Stimulation of gut and stomach mucosal morphology**

An intact gut mucosa with a preferably high surface is vital for efficient nutrient absorption. Many trials show that organic acids improve the condition of the mucosa:

### **Organic acids stimulate cell proliferation**

In an *in vitro* trial with pig hindgut mucosa, butyric acid stimulated epithelial cell proliferation in a dose-dependent manner ([Sakata et al., 1995](#)).

Blank et al. reported that fumaric acid, being a readily available energy source, may have a local trophic effect on the small intestines' mucosa. Due to faster recovery of the gastrointestinal epithelial cells after weaning, this trophic effect may increase the absorptive surface and digestive capacity in the small intestines.

### **Organic acids influence villi length and crypt depth in the gut**

[Ferrara et al.](#) (2016) observed a trend toward longer villi with a mixture of short-chain organic acids and mid-chain fatty acids, compared to the negative control.

The addition of Na-butyrate to the feed leads to increased crypt depth, villi length, and mucosa thickness

in the distal jejunum and ileum, according to [Kotunia et al.](#) (2004). However, the villi length and mucosa thickness were reduced in the duodenum.

According to [Gálfi and Bokori](#) (1990), a diet with 0.17% sodium butyrate increased the length of ileal microvilli and the depth of caecal crypts in pigs weighing between 7 and 102 kg.

## Organic acids strengthen stomach mucosa

[Mazzoni et al.](#) (2008) reported that sodium butyrate applied orally at a low dose influenced gastric morphology and function (thickening the mucosa), presumably due to its action on mucosal maturation and differentiation.

## 2.4 Pigs can use organic acids as an energy source

Organic acids are usually added to the feed in small doses. As some organic acids are intermediary products of the citric acid cycle, they are an energy source after being absorbed through the gut epithelium by passive diffusion. Their gross energy can be fully metabolized ([Pearlin et al.](#), 2019; [Roth and Ettle](#), 2005; [Suiryanrayna and Ramana](#), 2015).

The gross energy supply varies according to the acid. [Roth and Ettle](#) (2005) determined values between 6 kJ/g (formic acid) and 27 kJ/g (sorbic acid). [Pearlin et al.](#) (2019) calculated that 1 M of fumaric acid generates 1.340 kJ or 18 M ATP; this is comparable to the energy provision of glucose. Citric acid's energy provision is similar; acetic and propionic acid require 18 and 15 % more energy to generate 1 M ATP.

## Acidifiers improve immune response

The immune system, especially at the sensitive life stage of weaning, plays an essential role for the piglet. Acidifiers have been shown to stimulate or support the immune system. [Ahmed et al.](#) (2014) showed that citric acid (0.5 %) and a blend of acidifiers composed of formic, propionic, lactic, phosphoric acid + SO<sub>2</sub> (0.4 %) significantly increased the level of serum IgG. IgG are part of the humoral immune system. They mark foreign substances to be eliminated by other defense systems.



In a trial conducted by [Ren et al.](#) (2019), piglets receiving a mixture of formic and propionic acid showed lower concentrations of plasma tumor necrosis factor- $\alpha$ , regulating the activity of diverse immune cells. Furthermore, interferon- $\gamma$  and interleukin (IL)-1 $\beta$  were lower than in the control group after the challenge with *E. coli* (ETEC). In this trial, the addition of organic acids to the feed alleviated the inflammatory response in a way comparable to antibiotics.

## In a nutshell

Organic acids are no longer seen as pure acidifiers but as growth promoters and potential antibiotic substitutes due to their positive effect on the gastrointestinal tract. Their main effect, the decrease of pH, entails consequences from inhibiting pathogenic bacteria and improved digestion to enhanced health and growth.

Research indicates that acidifiers can be a viable alternative to antibiotic growth promoters and ZnO for ensuring healthy piglet production after weaning.

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# Piglet performance with fewer antimicrobials is possible



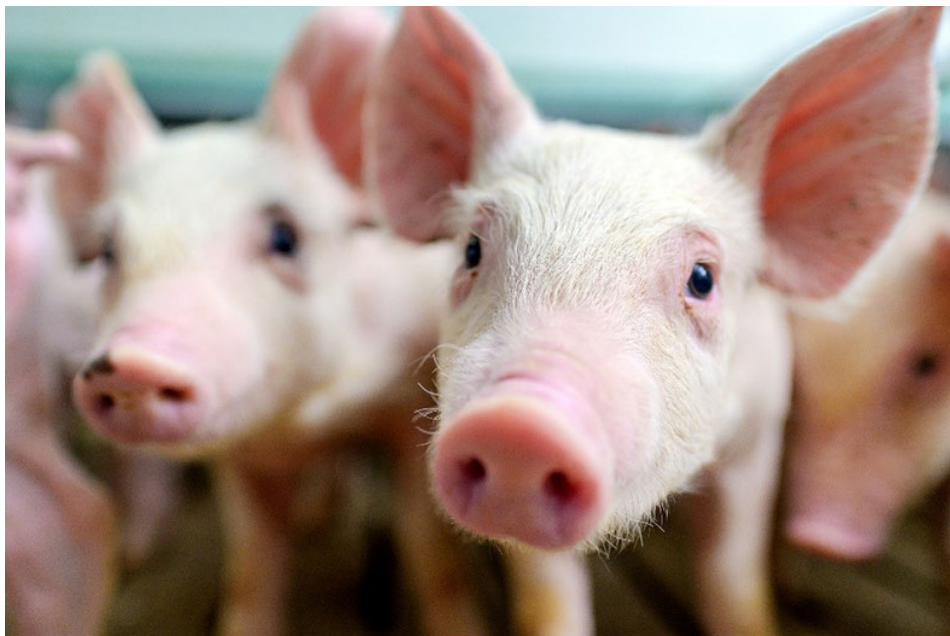
*By Technical Team, EW Nutrition*

**A variety of stressors simultaneously occur at weaning, making this probably the most challenging period in pig production. During weaning, we commonly see altered gut development and gut microbiome, which increases piglets' vulnerability to diseases. The most classic clinical symptom resulting from these stressors is the occurrence of post-weaning diarrhea. It is a sign that something went wrong, and piglet development and overall performance may be compromised (Guevarra et al. 2019).**

Besides weaning, an unavoidable practice in pig production, the swine industry has been facing other changes. Among them, the increased pressure to reduce the use of antimicrobials stands out. Antimicrobials are often associated with improved piglet performance and health. Their usage has been reduced worldwide, however, due to the threat of antimicrobial resistance that affects not just animal health but also human health (Cardinal et al., 2019).

# Reduce antimicrobials and post-weaning diarrhea: can piglet nutrition achieve both?

With these drastic changes for the piglets and the global swine industry, producers must find solutions to keep their farms profitable — especially from a nutritional perspective. Our last [article](#) presented two feed additives that can be part of an antibiotic-free concept for post-weaning piglets. This article will highlight a few essential nutritional strategies that swine producers and nutritionists must consider when formulating post-weaning feed without or with reduced amounts of antimicrobials.



## What makes weaning so stressful for piglets?

Producers, nutritionists, and veterinarians all agree that weaning is a tough time for piglets (Yu et al., 2019) and, therefore, a challenge to all those involved in the pig production chain. Although there is a global trend towards increasing weaning age, generally speaking, animals are still immature when going through the weaning process. They face several physiological, nutritional, and environmental changes (figure 1).

### Healthy piglets after weaning

Understanding the challenges to provide the right support

#### Weaning compromises piglet well-being and performance



Early and abrupt separation from the sow



High infectious pressure



Diet change - leaving the milk behind



Water quality and supply



Environmental stress and new roommates



Figure 1. Factors associated with weaning can compromise piglet well-being and performance

Most of these changes become “stressors” that trigger a cascade of reactions affecting the balance and morphology of the intestinal microbiome (figure 2). The outcome is a decrease in the piglets’ well-being and, in most cases, performance. We need to clearly understand how these stressors affect pigs to develop effective strategies against post-weaning growth impairments, especially when no antimicrobials are allowed.

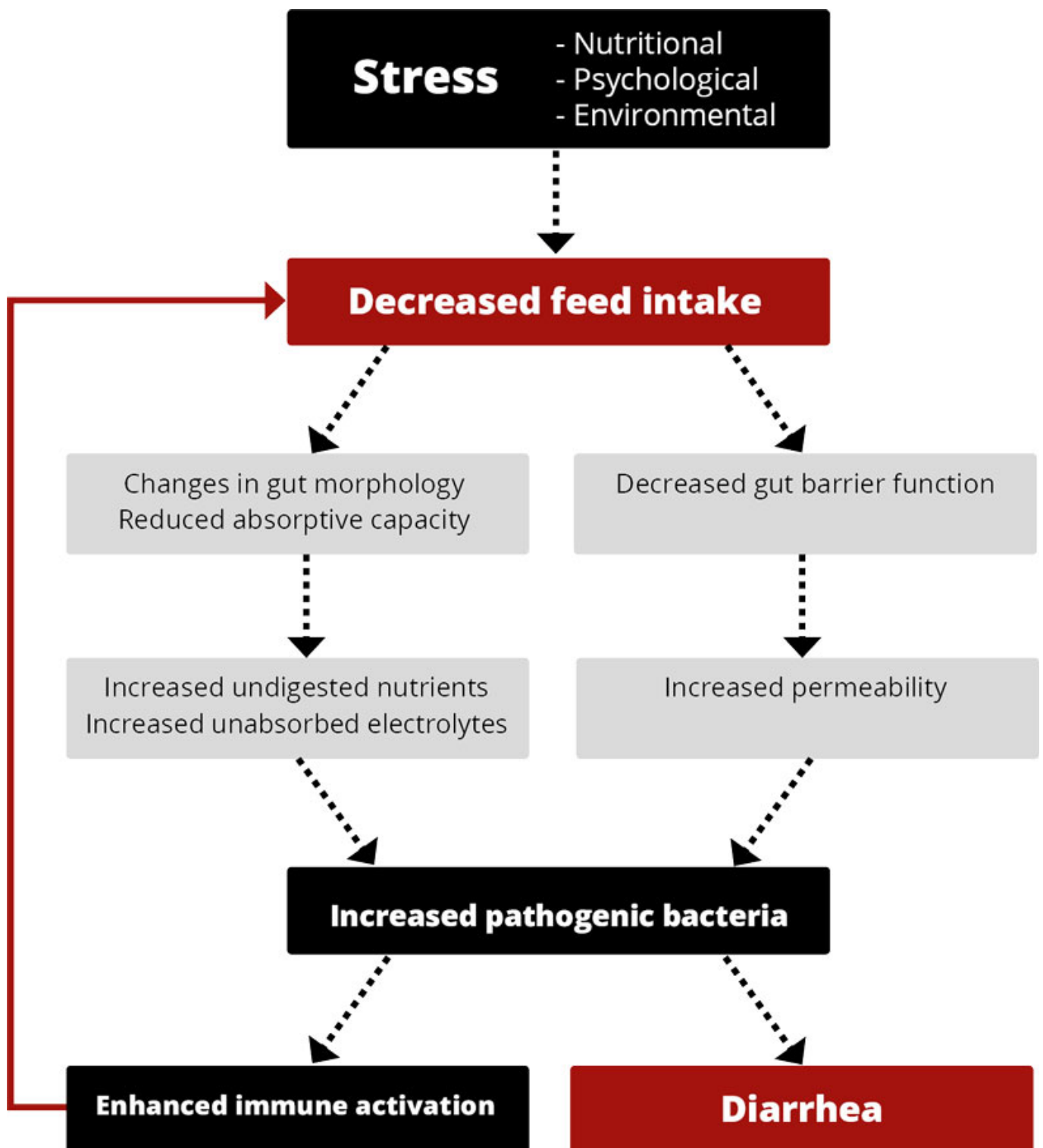


Figure 2. Schematic diagram illustrating the effects of stress in weaned piglets (adapted from Jayaraman and Nyachoti, 2017)

# Weaning support starts before weaning

The use of creep feed has been evaluated and even criticized for many years. Some operations are still reluctant to use such a feed due to its high cost and amount of labor on the farm, with manually providing feed and cleaning feeding trays. In addition, some questions have been raised regarding the ideal composition of the creep feed – how much complexity should we add to this special diet?

Therefore, the benefits of creep feed are under re-evaluation, not only considering piglet physiology per se, but also feed characteristics and different feeding programs. Recent studies have questioned highly complex creep feed formulations. Creep feed is being called “transition feed” (Molist, 2021) – i.e., that meal which is complementary to sows’ milk and not a replicate of it, helping piglets during the period of changing its main source of nutrients. We must, therefore, look at it as a way of making piglets familiar with solid feed, as highlighted by Mike Tokach during the 2020 KSU Swine Day. Dr. Tokach also mentioned that the presence of feeders in the lactation pen could stimulate the exploratory behaviors of the piglets. Combined, these practices can lead to a higher feed intake and performance during the nursery phase.

## Towards a pragmatic stance on creep feed

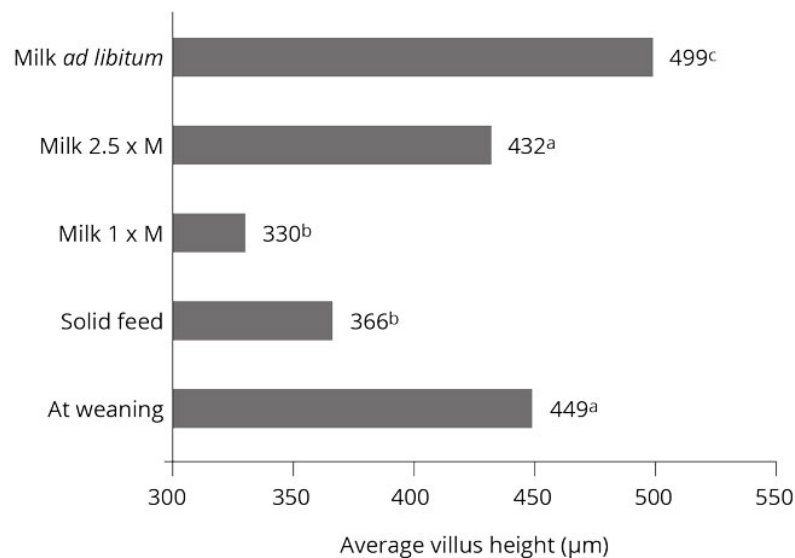
Heo et al. (2018) evaluated three different creep feed types: a highly digestible creep feed, weaning feed as creep feed, and sow feed as creep feed until weaning. Piglets receiving the highly digestible creep had higher feed intake during the second to the last week pre-weaning (14 to 21 days of age) and higher ADG during the last week pre-weaning (21 to 28 days of age). This resulted in a trend for higher weaning weight. However, these benefits did not persist after weaning when all piglets received the weaning feed.

Guevarra et al. (2019) also suggested that the abrupt transition in piglet nutrition to a more complex nutrient source can influence shifts in the gut microbiota, impacting the absorptive capacity of the small intestine. Yang et al. (2016) evaluated 40 piglets from eight litters during the first week after weaning. They found that the change in diet during weaning reduced the proliferation of intestinal epithelial cells. This indicates that this period affects cellular macromolecule organization and localization, in addition to energy and protein metabolism. These results suggest that “similarity” in feed pre- and post-weaning may contribute more to the continuity of nutrient intake post-weaning than a highly complex-nutrient dense creep feed.

## Nutritional strategies without antibiotics: focus on pig physiology

As mentioned, it is crucial to avoid a drastic drop in feed/nutrient intake after weaning compared to pre-weaning levels. In a classic study, Pluske et al. (1996) showed the importance of high intake levels on villus weight (used as a reference for gut health, cf. graph 1). Although not desirable, the reduction should be considered “normal” behavior.

Imagine these recently weaned piglets, facing all these stressors, having to figure out within this new group of peers when it is time to eat, where to find food, why water and food now come from two distinct sources... Therefore, management, feeding, water quality, and other aspects play important roles in post-weaning feed intake (figure 3).

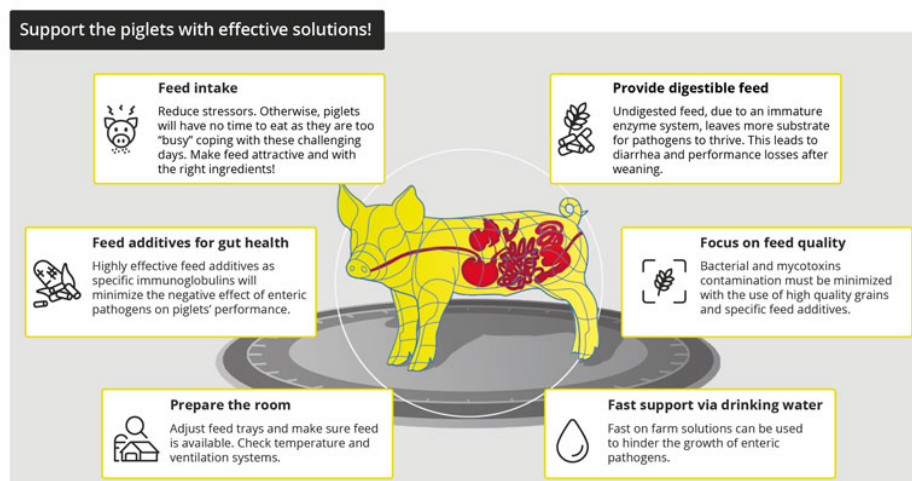


*Graph 1. Villus height following different levels of feed intake (M = maintenance) post-weaning (a.b.c bars with unlike superscript letters are different at  $P < 0.05$ ). (From Pluske et al., 1996.)*

From a nutritional perspective, piglets at weaning experience a transition from milk (a high-fat, low-carbohydrate liquid) to a plant-based diet (a solid, low-fat, and high-carbohydrate diet) (Guevarra et al., 2019). Even when previously introduced to solid feed, it is still difficult for their enzymatic system to cope with grains and beans.

One of the consequences of the lower digestibility capacity is an increase of undigested nutrients. Harmful bacteria thrive and cause diarrhea, reducing even further an already compromised feed intake. This cycle must be broken with the support of formulations based on piglet physiology.

Post-weaning feed must support digestion and nutrient absorption, including the largest possible share possible of high-quality, digestible ingredients, with low anti-nutritional factors. High-performing feed also integrates functional amino acids, functional carbohydrates, and additives to support the intestinal mucosa and gut microbiome.



*Figure 3. Supporting piglets with effective solutions*

# Crude protein - more of the same?

Levels of crude protein in piglet feed have been in the spotlight for quite some time. The topic can be very controversial where the exact percentage of crude protein in the final feed is concerned. Some nutritionists pragmatically recommend maximal levels of 20% in the weaner feed. Others go a bit lower, with some formulations reaching 17 to 18% total crude protein. Levels above 20% will incur high costs and may accentuate the growth of pathogenic bacteria due to a higher amount of undigested protein in the distal part of the small intestine (figure 4).

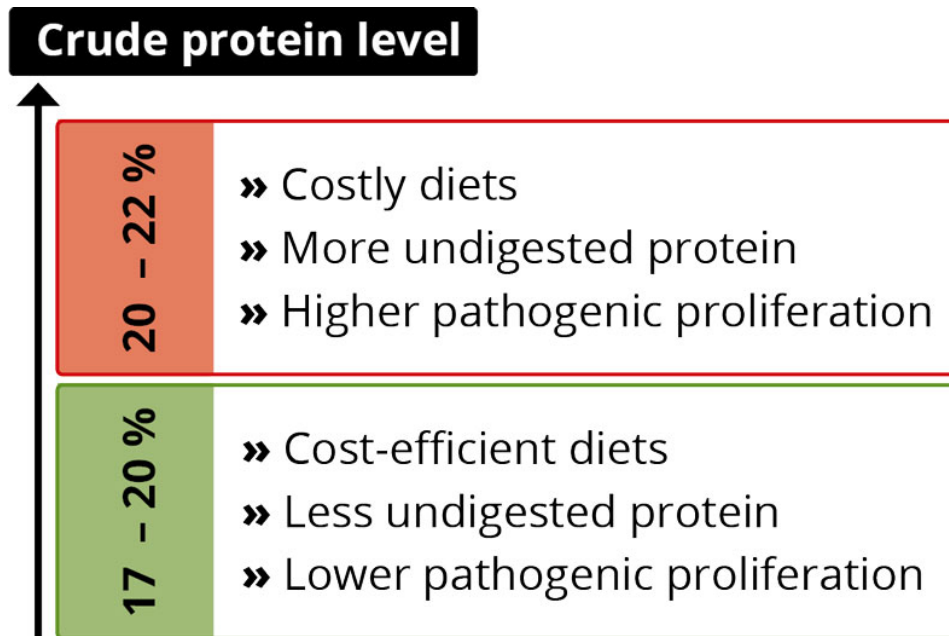


Figure 4. The dynamics of crude protein levels in piglet feed

What is not open for discussion, however, is the quality of the protein used, in terms of:

- digestibility,
- the total amount of anti-nutritional factors, and
- the correct supply of essential and non-essential amino acids (particularly lysine, methionine, threonine, tryptophane, isoleucine and valine).

## The critical role of digestibility

High-digestibility ingredients for piglets need to deliver minimum 85% digestibility. In most cases, to reach high biological values (correlating to high digestibility), these ingredients typically undergo different processing steps, including heat, physical, and chemical treatments. Animal by-products (such as hydrolyzed mucosa, fish meal, spray-dried plasma) and processed vegetable sources (soy protein concentrate, extruded grains, potato protein) can be used in high amounts during this phase. They will notably reduce the total amount of undigested protein reaching the distal part of the intestine, with 2 main benefits:

- Less substrate for pathogenic bacteria proliferation (and therefore lower incidence of diarrhea)
- Lower nitrogen excretion to the environment





It is common knowledge that certain storage proteins from soybean meal (for instance, glycinin and B-conglycinin) can cause damage to piglets' intestinal morphology and trigger the activation of the immune system. However, it is normal practice to introduce this ingredient to piglets around weaning so that the animals can develop a certain level of tolerance to such compounds (Tokach et al., 2003). In Europe, where most diets are wheat-barley based, soybean meal is included in levels varying from 3 to 9% in the first 2 diets, with gradual increases during the nursery phase.

## Amino acids and protein: manage the balance

When the supply and balance between essential and non-essential amino acids is concerned, reducing total crude protein brings indeed complexity to the formulations. The concept of ideal amino acid should be expanded, ideally, to all 9 essential amino acids (lysine, methionine, tryptophan, threonine, valine, isoleucine, leucine, histidine, and phenylalanine). In most cases, formulations go up to the 5<sup>th</sup> or 6<sup>th</sup> limiting amino acid. Lawor et al. (2020) suggest 2 practical approaches to avoid deficiencies when formulating low-protein piglet feed:

- Maintain a maximum total lysine to crude protein ratio in the diet of 7.1 to 7.4%
- Do not exceed the SID lysine to crude protein ratio of 6.4%

Some conditionally essential amino acids (e.g. arginine, proline, and glutamine) also play critical roles in diets with reduced crude protein levels. Glutamine is especially interesting. When supplemented in the feed, it can be used as a source of energy by the intestinal epithelium and, therefore, prevent atrophy and support nutrient absorption, resulting in better growth post-weaning (Hanczakowska and Niwińska, 2013; Watford et al., 2015)

# The importance of the buffer capacity of the feed - supporting the enzymatic system

Given the move towards antibiotic reduction, this topic is more relevant than ever to nutritionists worldwide. The acid-binding capacity (also known as buffering capacity) of the feed directly affects the capacity of the stomach to digest protein. Hence, buffer capacity is of utmost importance in antimicrobial-free diets as it influences the growth of pathogenic bacteria (Lawlor et al., 2005).

In short, the acid-binding capacity is the resistance of an ingredient or complete feed to pH change. For piglet feed/feed ingredients, it is normally measured by the acid-binding capacity at pH4 (ABC-4). A higher ABC-4 equates to a higher buffering capacity. Feed with a high ABC-4 would require large amounts of [gastric acid](#) for the pH of the stomach to reach 4 and below. As the post-weaned piglet has limitations on producing and secreting acid, the stomach pH would stay high and, thus, less favorable for protein digestion.

The recommendation is to have a complete feed based on single ingredients with low ABC-4 values and to use additives that further reduce the ABC-4 value (such as organic acids). According to Molist (2020), post-weaning feed must have an ABC-4 that is lower than 250-300 meq/kg.

## Talking about fiber

Dietary fibers are also known for regulating intestinal health in both humans and animals. Chen et al. (2020), for example, examined the effects of dietary soluble fibers (inulin) and insoluble fibers (lignocellulose) in weaned piglet diets for four weeks. Results showed that combining those fibers can positively influence nutrient digestibility, gut microbiota composition, intestinal barrier functions, and growth performance (table 1 ).

| Items <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Control                   | IDF                        | SDF                        | CRMDF                      | MDF                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|----------------------------|----------------------------|----------------------------|--------------------------|
| Initial weight, kg                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 7.47 ± 0.16               | 7.47 ± 0.12                | 7.48 ± 0.09                | 7.48 ± 0.13                | 7.48 ± 0.12              |
| 2wk weight, kg                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 10.89 ± 0.26              | 11.20 ± 0.33               | 10.76 ± 0.26               | 11.23 ± 0.17               | 11.14 ± 0.21             |
| Final weight, kg                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 16.93 ± 0.42              | 17.15 ± 0.77               | 16.69 ± 0.58               | 17.95 ± 0.44               | 17.41 ± 0.20             |
| 1-14 d                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                           |                            |                            |                            |                          |
| ADFI, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 403 ± 19.13               | 410 ± 11.47                | 376 ± 15.49                | 409 ± 10.57                | 399 ± 10.55              |
| ADG, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 238 ± 10.37               | 264 ± 17.04                | 230 ± 17.59                | 261 ± 5.84                 | 264 ± 10.00              |
| F/G                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1.70 ± 0.08 <sup>a</sup>  | 1.58 ± 0.08 <sup>ab</sup>  | 1.66 ± 0.07 <sup>ab</sup>  | 1.57 ± 0.01 <sup>ab</sup>  | 1.51 ± 0.02 <sup>b</sup> |
| Diarrhoea incidence %                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 21.42 ± 5.53              | 12.54 ± 4.19               | 17.86 ± 7.55               | 15.48 ± 4.29               | 15.48 ± 3.40             |
| 15-28 d                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                           |                            |                            |                            |                          |
| ADFI, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 716 ± 34.86               | 732 ± 38.27                | 699 ± 30.97                | 756 ± 32.79                | 715 ± 24.96              |
| ADG, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 431 ± 29.13               | 425 ± 37.50                | 424 ± 28.15                | 480 ± 24.13                | 448 ± 8.23               |
| F/G                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1.68 ± 0.06               | 1.68 ± 0.05                | 1.67 ± 0.07                | 1.58 ± 0.04                | 1.60 ± 0.05              |
| Diarrhoea incidence %                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 16.67 ± 2.38 <sup>a</sup> | 10.71 ± 2.92 <sup>ab</sup> | 10.71 ± 3.03 <sup>ab</sup> | 10.00 ± 1.23 <sup>ab</sup> | 3.57 ± 0.60 <sup>b</sup> |
| 0-28 d                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                           |                            |                            |                            |                          |
| ADFI, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 560 ± 21.22               | 571 ± 24.41                | 537 ± 21.32                | 583 ± 19.25                | 557 ± 15.72              |
| ADG, g/d                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 334 ± 12.20               | 345 ± 25.20                | 327 ± 19.24                | 371 ± 13.01                | 356 ± 6.98               |
| F/G                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1.68 ± 0.03 <sup>a</sup>  | 1.63 ± 0.03 <sup>ab</sup>  | 1.66 ± 0.05 <sup>ab</sup>  | 1.57 ± 0.03 <sup>b</sup>   | 1.56 ± 0.03 <sup>b</sup> |
| Diarrhoea incidence %                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 19.05 ± 2.71              | 11.43 ± 4.01               | 14.29 ± 5.03               | 15.48 ± 4.08               | 9.52 ± 1.99              |
| <sup>a-b</sup> Means in the same row, different superscript letters show significant difference (P<0.05).<br><sup>1</sup> <b>Control</b> : basal diet; <b>IDF</b> : 1% insoluble fiber; <b>SDF</b> : 1% soluble fiber; <b>CRMDF</b> : 0.75% insoluble fiber + 0.25% soluble fiber / 0.25% insoluble fiber + 0.75% soluble fiber; <b>MDF</b> : 0.5% insoluble fiber + 0.5% soluble fiber;<br>ADFI: average daily feed intake; ADG: average daily gain; F/G: feed/gain. |                           |                            |                            |                            |                          |

Table 1. Effects of dietary fiber supplementation on piglet growth performance (adapted from Chen et al., 2020)

## How to reduce antimicrobials? Understand the

# roles of piglet physiology and nutrition

Swine producers might think that “How can I reduce antimicrobial use on my farm?” and “How can I improve the performance of piglets at weaning?” are two separate questions. However, that is not always the case. Answers based on a deep understanding of physiology and nutrition dynamics help piglets overcome the challenges encountered during weaning – and, thus, lessen the need for antimicrobial interventions.

In this article, we have explored the basic principles that are the basis for ensuring the performance and health of the post-weaning piglet. Although we do not have a singular solution for eliminating antimicrobials on our pig farms, we can count on a group of robust and integrated nutritional strategies. By integrating factors ranging from management to feed additives, these solutions can improve piglet health and performance throughout their lives.

**[To know more about Gut health products click here.](#)**